THE ENGINEER.

The White Star Line.

THE WHITE STAR LINE.

IT is perhaps not generally known that the flag which now floats over the thirty odd steamers forming the fleet of the White Star Line, is the same that once flew from the mastheads of a fleet of sailing clippers years before the introduction of steam as the motive agent in the mercantile marine. The origin of the White Star Line really dates from the epoch of the great rush to the gold diggings of Australia, some sixty years ago; when in a period of about seven years, over half a million adventurers were said to have been transported to the gold-fields.

An important change occurred in 1867, when the managing owner of the White Star Line retired, and the flag was taken over by Mr. Thomas Henry Ismay, who began by introducing iron sailing ships in place of the wooden clippers formerly employed. One of these ships, called the Bluejacket, is illustrated in Fig. 2. Next came the greatest event in the history of the White Star flag, namely the establishment in 1869 of the Oceanic Steam Navigation Company, Limited. This was accomplished by Mr. Ismay, who, in 1870, was joined in the management by Mr. G. Hamilton Fletcher and Mr. William Imrie, of the late firm of Imrie, Tomlinson and Co., and in whose office Mr. Ismay and Mr. Imrie had been fellow apprentices. The title of the firm then was altered to Ismay, Imrie and Co. Mr. Ismay had already gained some experience with steamships as director of the National Line, which was established in 1863, in Liverpool, with three steamers called the Louisiana (later named the Holland), Virginia, and Pennsylvania. It is interesting here to recall the fact that the National Steamship Company had the honour to be the first to introduce compound engines in the Atlantic trade, the Holland having had the original engines, with two cylinders, each 55in. diameter and 3ft. stroke, removed in 1869, and replaced by compound engines built by J. Jack and Co., Liverpool. These engines had two cylinders, one high-pressure, 46in. diameter, and one low-pressure, 86in. diameter by 4ft. stroke, with a boiler pressure of 60 lb. per square inch.

Mr. Ismay conceived the idea of establishing a really high-class service of passenger ships to serve the Transatlantic trade, and an order, with a free hand, was given to Messrs Harland and Wolff, of Belfast, to build a new fleet, the first of which was the Oceanic, Fig. 1, launched in August, 1870. This vessel made her appearance in the Mersey in February, 1871. Her chief dimensions were:—Length, 420ft.; breadth, 41ft.; depth, 31ft.; and tonnage, 3707. The Oceanic at one step quite eclipsed any vessel previously seen in the Mersey, and can be considered the pioneer of improvements which have since made travelling across the Atlantic a luxury. The builders put aside to a large extent the hitherto accepted ideas of steamship design, and, instead of the usual high bulwarks and narrow wooden deck houses, another iron deck was added with open railings for bulwarks. The saloon, too, was, for the first time, placed amidships, and extended over the entire width of the vessel. Forward and aft of the saloon the state rooms were arranged along both sides, and as all the sidelights were of unusually large size, they gave a bright and airy appearance to the interior, which contrasted with the older ships much to the latter's disadvantage. The motive mechanism consisted of two sets of tandem compound four-cylinder engines, with two high-pressure cylinders, each 41in. diameter, and two low-pressure cylinders, each 78in. diameter, working on two cranks, with a stroke of 5ft. Each engine (forward and aft) formed a complete unit in itself, a feature of importance in case of breakdown. There were twelve boilers, with a total of twenty-four furnaces, and working at 65 lb. pressure per square inch. These consumed 65 tons of coal per day, and the speed of the ship was 14 knots. These engines were similar to those of the Britannic, of which we give an illustration on page xii., were built by Maudslay, Sons and Field, London, and worked admirably.

When she was first laid down the Oceanic was intended for the Australian trade *viâ* the Suez Canal, which was just about to be opened, but this idea was abandoned and the vessel was put into the "Atlantic Ferry" service, where her regular running and high speed soon made her famous. According to Mr. Maginnis, in his interesting book "The Atlantic Ferry," the Oceanic first sailed for New York on March 2nd, 1871, but had to put in to Holyhead owing to serious heating of the main bearings and crank-pins. After a few days' delay she proceeded to New York where she was visited by an immense number of people. When she had completed a few voyages the Oceanic returned to Belfast to have alterations made, amongst which were the shortening of the four masts, the addition of a whale-back at the forward end and the increase of her steam raising power by the addition of two boilers. The saloon accommodation was also improved. The vessel continued in the New York service, making trips from Queenstown to New York in 8½ days, until 1875, when she sailed from Liverpool for Hongkong *viâ* the Suez Canal, there to open with the first Belgic and Gaelic, a service on the Pacific between that port, Yokohama and San Francisco. One returned to Liverpool in 1879 to be brought up to date in respect of both passenger accommodation and machinery, and sailed again on March 16th, 1880, with new boilers and modified machinery, calling at Suez, Hongkong, and Yokohama, and arrived at San Francisco on June 6th, thus enabling passengers to complete a circuit of the globe by reaching Liverpool again in 75 days from leaving, against 80 days taken up till then. On her sixty-second voyage in October, 1889, the Oceanic made what was at that time the fastest passage on record across the Pacific, crossing from Yokohama to San Francisco in 13 days 14 hours 4 minutes. The vessel remained in the Pacific service until late in 1895, when

Fig. 1—THE FIRST OCEANIC, 1871

she returned to Belfast with the intention of having new engines and boilers fitted. The idea was, however, abandoned, and rather than see the famous "Greyhound" descend to tramp service she was sold for £8000, and left Belfast on February 10th, 1896, to be broken up.

Following the launching of the Oceanic in 1870, in quick succession came the Baltic, Republic, and Adriatic from Messrs. Harland and Wolff's yard. These were all in commission in the spring of 1872, and in October of the same year the first Celtic was added to the fleet. Shortly afterwards the same builders delivered four more steamers called the Asiatic, Tropic, Gaelic, and Belgic, which were afterwards sold.

In 1874 and 1875 two larger ships, but of similar type, were built, namely, the Britannic, Fig. 3, and Germanic. Each measured 455ft. long, 45ft. broad, 33¾ft. deep, and had a tonnage of 5004. These extremely successful boats were built by Harland and Wolff, and the engines were supplied by Maudslay, Sons and Field. These were of the two-crank compound tandem type, like those of the Oceanic, but larger, the high-pressure cylinders being 48in. in diameter and the low pressure 83in., with a stroke of 5ft. Steam at 75 lb. pressure was generated in eight double-ended so called elliptical boilers — see page xi.—having thirty-two furnaces at 75 lb. pressure, and the coal consumption averaged about 110 tons per day, with a speed slightly over 16 knots. The diameter of the crank shaft was 19⅝in. and the propeller shaft 18in. The propeller had a boss with four steel blades bolted on, and was 23ft. 6in. diameter by 31ft. 6in. mean pitch. The engines developed about 4970 horse-power, and the coal consumption came out at only about 1.8 lb. per horse-power. The engines of the Oceanic, Baltic, Republic, Adriatic and Celtic, were all of the same type but of less power than those of the Britannic and Germanic. The Britannic and Germanic were the first vessels to reduce the time of passage to less than 7½ days.

In 1872 the United States of America selected the White Star ships to carry Saturday's mails from New York to Europe—and the company is still engaged in the mail service. The English mail contract speed was based on 12 knots, but even the old boats above mentioned averaged 14 knots. In 1873 the Company's fleet was composed of the following vessels: –

	Tons net, register.	Tons, gross.	H.P., nom.	Accommodation, saloon.
Britannic	3174	5004	760	220
Germanic	3174	5008	760	220
Celtic	2438	3888	650	150
Adriatic	2458	3888	650	150
Republic	2186	3707	600	140
Baltic	2209	3707	600	140
Oceanic	2439	3707	600	140
Gallic	1712	2651	400	50
Belgic	1716	2651	400	50

Some idea of the rate of progress made may be gathered from the number of passengers carried. From Liverpool to New York these amounted to 2666 in 1873, and from New York to Liverpool 2943.

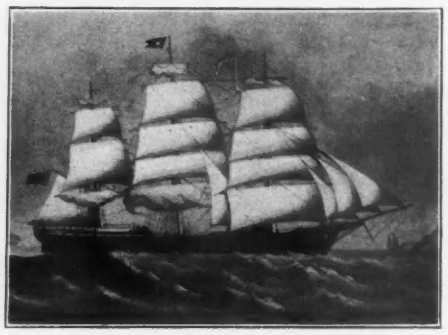


Fig. 2—IRON SAILING SHIP BLUEJACKET

In 1873 the company built extensive engineering works in Liverpool, which were afterwards transferred to Bootle. These works are equipped with all the necessary tools for carrying out repairs quickly and effectively, and we shall have something to say about them further on. In the same year the White Star Line concluded an arrangement with the Occidental and Oriental Steamship Company, of San Francisco, which had the effect of bringing China and Japan much nearer in point of time to London than by the Eastern route *viâ* Gâlle and Suez. Towards the end of 1874 the Occidental and Oriental Company, being desirous of establishing a line of steamers possessing rapid steaming powers for a new route between Hongkong, Yokohama, and San Francisco, decided to charter ships rather than build vessels of its own. It selected the Oceanic, Belgic, and Gaelic, and these boats were appointed by the United States and Japanese Governments to convey the mails, and by their means Japan was brought within a 32 days' journey of London.

In 1895 the Germanic was fitted with new triple-expansion engines at Belfast. Some three years later, in the winter of 1898-9, after having arrived at New York with her deck and upper works laden with snow and ice, she suddenly listed over and filled with water through the coal ports and sank. Although she was salved, all the internal fittings were practically destroyed, and had to be renewed.

The earliest steamers of the White Star Line were remarkable for their uniformity of steaming rather than high speed. Nevertheless they reduced the passage which had previously averaged 9½ to 10 days to about 8½ days. But it was left to the Britannic and Germanic to make a decided advance on the Atlantic records. The former in 1877 crossed from Queenstown to New York in 7 days 10 h. 50 min., thus beating by three hours the best previous performance of any competing liner. The Britannic subsequently eclipsed this performance on several occasions. In 1890, for instance, she did the trip in 7 days 6 h. 55 min., her daily runs being as follows:—292, 372, 377, 370, 376, 377, 387, 261 = 2812 knots; and the average speed 16.08 knots. The Germanic's performances bore a close resemblance to those of her sister ship, and when it is remembered that these, at that time, high speeds were obtained with their original compound engines and boilers on a small coal consumption and with their large carrying capacity, much credit is reflected on their designers.

An experiment was made by the White Star Line about this time to replace the oil lamps used on board ship by gas lighting. The gas was made from oil by an apparatus carried on board, which occupied about 1600 cubic feet of space. The first steamer so fitted was the Adriatic, followed shortly afterwards by the Celtic. Although the effect produced was a marked improvement, much trouble was caused by leaky pipes, produced by the working of the ship at sea, and the system had to be abandoned. A further experiment in the early seventies was made in the adoption of oscillating state-rooms and berths to counteract the motion in a sea-way, but, as in the case of the Bessemer, this had also to be abandoned.

The raising and lowering propeller was another ingenious idea tried by the White Star Line, but without success. The Britannic was the ship selected for this test, and a drawing and description will be found of her gear on a later page.

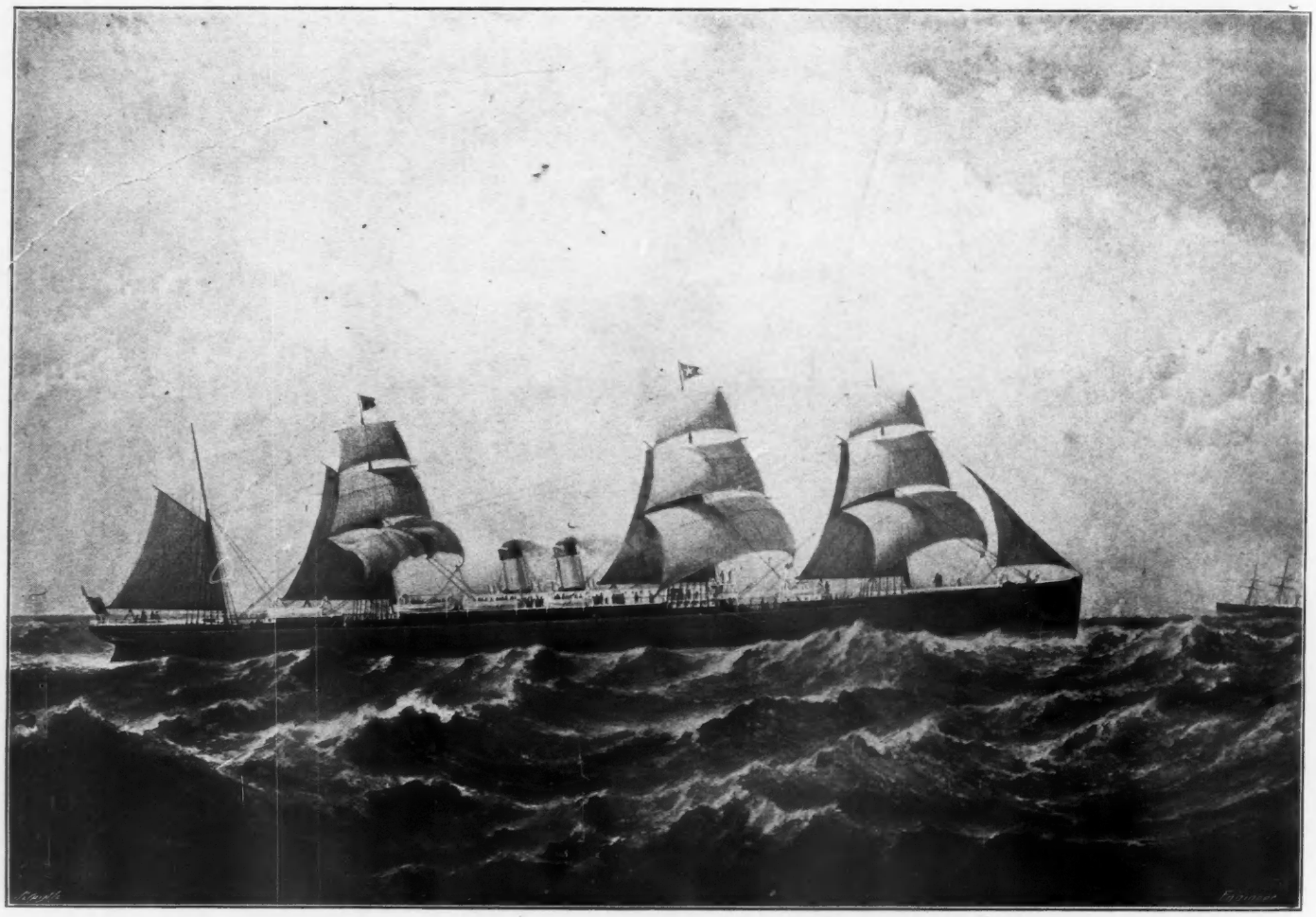


Fig. 3—THE BRITANNIC, 1874

Although the company's activities kept increasing with its range of operations, necessitating increases in the fleet, no striking departure in the ships was made until, in 1889, Messrs. Harland and Wolff commenced the building of the first twin-screw vessels Majestic and Teutonic, both of which are still in the company's service. The leading particulars of these sister ships are as follows:—

Length, overall	582ft.
,, between perpendiculars	568·8ft.
Breadth, moulded	57·5ft.
,, extreme	57·8ft.
Depth, moulded	42·2ft.
,, hold	39·3ft.
Displacement (light, 19ft. 2in.)	10,650 tons
,, (loaded, 29ft. 4½in.) ...	17,800 tons

These ships have four continuous steel decks, and are divided by twelve water-tight bulkheads. They are propelled by two sets of triple-expansion engines, with cylinders 43in., 68in., and 110in. diameter by 60in. stroke, which give 17,000 indicated horse-power and a speed of 19½ knots. The two propellers are of manganese bronze, 16ft. 3in. diameter and 20ft. 6in. pitch. The boilers are 16 in number, 4 being single-ended 10ft. long by 12ft. 6in. diameter, 8 double-ended 17ft. by 12ft. 6in., and 4 double-ended 17ft. by 12ft. The working pressure is 180 lb. per square inch, the grate area 1160 square feet, and the heating surface 40,968 square feet. The two ships present a different appearance from the earlier ships, as the four masts carried by the latter were replaced by three flag poles, sail power being thus

abandoned. The two funnels are spaced far enough apart to allow the saloon to be placed between them. The Teutonic, Fig. 5, sailed her first voyage in August, 1889, after having first done duty in the review of the British fleet at Spithead, where she was the first Atlantic liner to appear as a fully armed and equipped cruiser. The sister

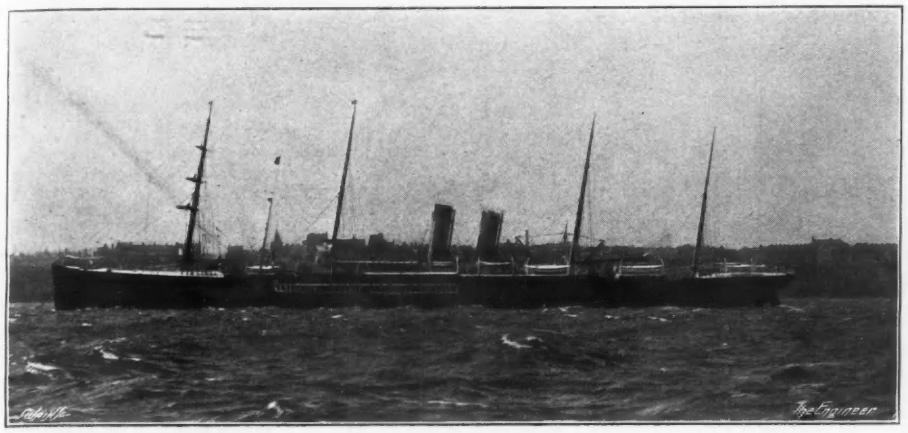


Fig. 4—THE BRITANNIC WITH TENDER

ship Majestic made her first voyage in April, 1890. In 1903 the Majestic returned to the builders' yard for an extensive overhaul of her machinery and passenger accommodation. The mizzen mast was also removed, and the main mast placed further aft. These ships were followed by further twin-screw vessels, namely, the Nomadic and Tauric in 1891; Bovic, 1892; Gothic and Cevic in 1893; Georgic in 1895, Delphic in 1897, Cymric in 1898, and the Afric, Medic, Persic, Runic, Fig. 9, and Suevic, in 1899.

The Oceanic, Fig. 7, &c.—the second of this name—marked a new epoch in the White Star fleet. She sailed on her first voyage on September 6th, 1899, and was the first vessel launched since the Great Eastern, which exceeded the latter ship in length. She carries 1500 passengers of all classes, who, together with the crew, make the number of 2000 lives on board. The Oceanic's general outline and arrangements resemble somewhat those of the Teutonic, but are on a more generous scale. The following are the leading particulars of the Oceanic:—

Length, overall	705ft. 6in.
,, between perpendiculars	685ft. 7in.
Breadth, moulded	68ft.
,, extreme	68·35ft.
Depth, moulded	49·62ft.
,, hold	44·5ft.

When light the Oceanic displaces 18,300 tons, and when loaded to a draught of 35ft. 7in., 31,590 tons. She carries 2410 tons of water ballast, has four continuous steel decks, and is divided by 13 water-tight bulkheads. She is propelled by twin screws, driven by two sets of triple-expansion inverted four-crank engines of the following dimensions:—

$$47\tfrac{1}{2}\text{in.} + 79\text{in.} + 93\text{in.} + 93\text{in.} \times 72\text{in.}$$

The total indicated horse-power of the engines is 28,000, and the average speed of the vessel 20½ knots. The propellers are of manganese bronze, 22ft. 3in. diameter by 32ft. pitch. The boilers are fifteen in number, ten being 18ft. 6in. by 15ft. 3in., three 18ft. by 16ft. 6in., and two 18ft. 6in. by 14ft. 10in.; there are 96 furnaces with grate area 1962 square feet, and the total heating surface is 74,686 square feet.

Apart from the two leviathan steamships which are now being built by Harland and Wolff, Limited, at Belfast, namely, the Olympic and Titanic, the White Star fleet at present comprises some 30 vessels. Of these, the Adriatic, twin screw, 25,000 tons, the Oceanic, twin screw, 17,273 tons, the Majestic, twin screw, 10,000 tons, and the Teutonic, twin screw, 10,000 tons, are mail and passenger steamers engaged in the Southampton and Cherbourg-Queenstown-New York service, calling at Plymouth on the eastward passage. The Baltic, twin screw, 23,876 tons, Cedric, twin screw. 21,035 tons, the Celtic, twin screw, 20,904 tons, and the Arabic, twin-screw, 15,801 tons, are engaged in the Liverpool-Queenstown-New York service. The Cretic, twin screw, 13,507 tons, Cymric, twin screw, 13,096 tons, Canopic, twin screw, 12,096 tons, and Romanic, twin screw, 11,394 tons, are engaged in the Liverpool-Queenstown-Boston-New York-Boston Mediterranean service. All the above-mentioned boats carry mails and passengers. Between Liverpool, Quebec and Montreal, the two latest steamers of the fleet are engaged, namely, the Laurentic, triple screw, 14,900 tons, and the Megantic, twin screw, 14,900. These are the largest boats engaged in the Canadian trade.

Between Sydney, Australia, and London, the White Star Company has a fleet of five steamers in constant service. These are named the Afric, twin screw, 11,948 tons, Persic, twin screw, 11,974 tons, Suevic, twin screw, 12,531 tons, Medic, twin screw, 11,914 tons, and the Runic, twin screw, 12,482 tons, these being the largest steamers sailing from the United Kingdom in the Australian trade. Between New Zealand and this country there are four twin-screw steamers engaged, namely, the Delphic, 8273 tons, Athenic, 12,234 tons, Corinthic, 12,231 tons, and the Ionic, 12,252 tons, the three last named being the largest vessels in the New Zealand trade. The company also owns three tenders, two for passengers, the Magnetic, twin screw, 619 tons, and the Gallic, 311 tons, while the Pontic is a baggage tender of 395 tons. The above list embraces the whole of the trading fleet and tenders. There has, however, been recently added a training ship called the Mersey, 1829 tons, of which we shall give particulars.

The Laurentic—Fig. 14—was launched on September 10th, 1908, and is of peculiar interest to engineers, owing to the adoption in this vessel of the system of marine propulsion by means of a combination of reciprocating engines with a low-pressure steam turbine. The sailing of this fine passenger steamer from Liverpool on April 29th, 1909, also commenced a new epoch in the White Star services, as it signalised the entry of this line into the Canadian trade. She was built by Harland and Wolff, Limited, at Belfast, and is a triple screw steamer, each of the wing propellers being driven by four-crank triple balanced engines, and the central propeller by a turbine. The object aimed at is to retain the advantages of well-balanced reciprocating engines, and at the same time obtain the benefit of the further expansion of steam in a low-pressure turbine, while avoiding the necessity for an astern turbine which is fitted in steamers driven by turbines only.

The Laurentic and Megantic are the largest vessels in the Canadian trade; in fact, they are too large to navigate the river St. Lawrence during the winter season, when they have to be transferred to other services. They are

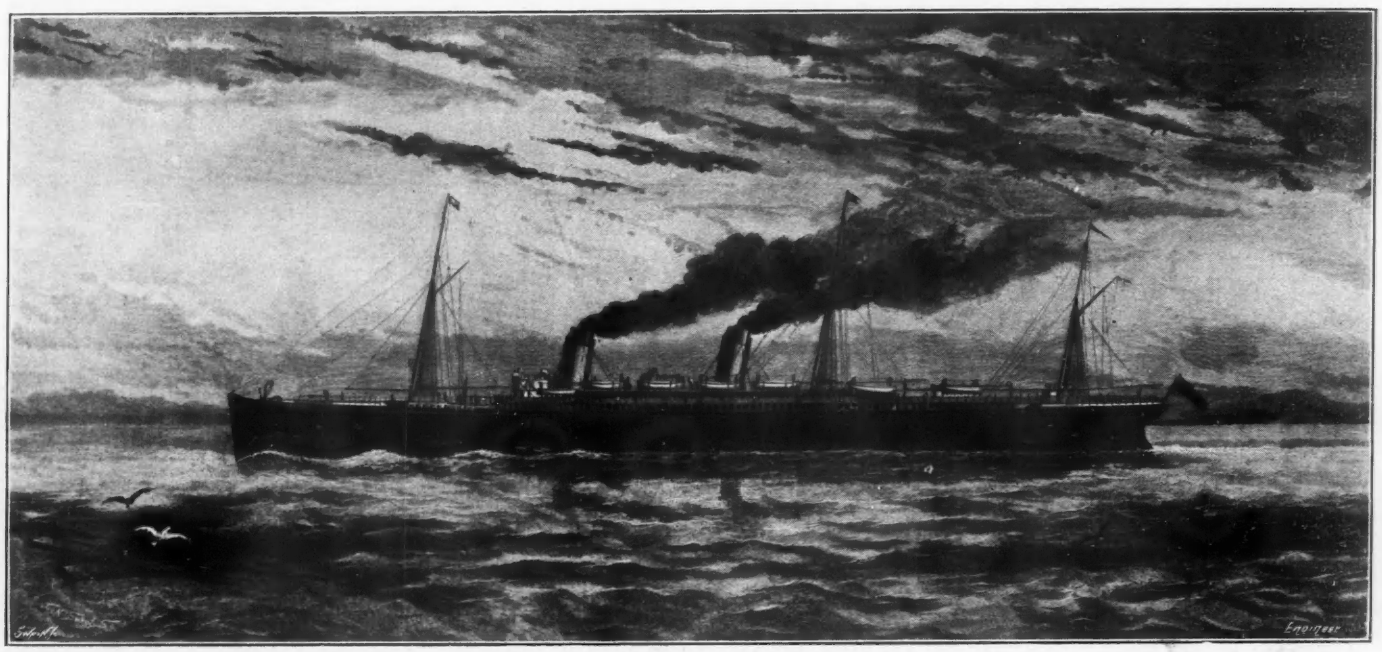


Fig. 5—THE TEUTONIC, 1889

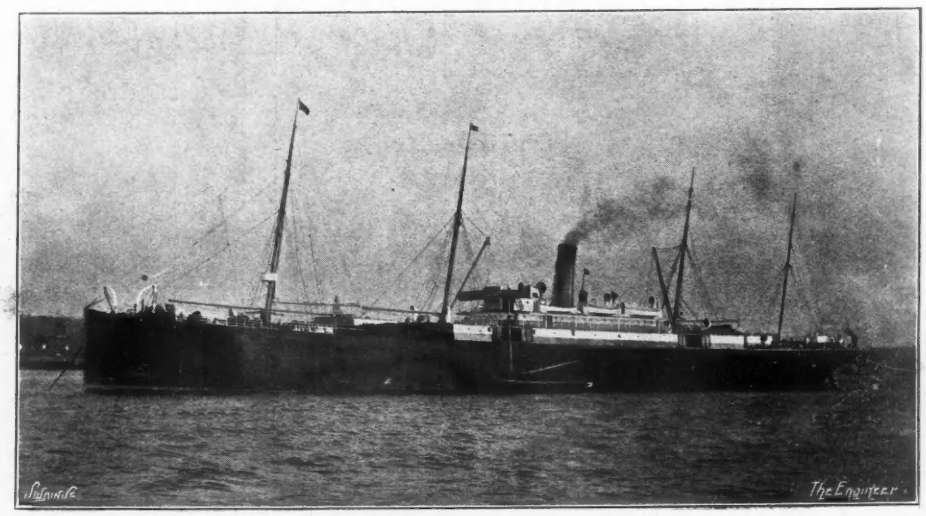


Fig. 6—THE CARGO BOAT CEVIC, 1893

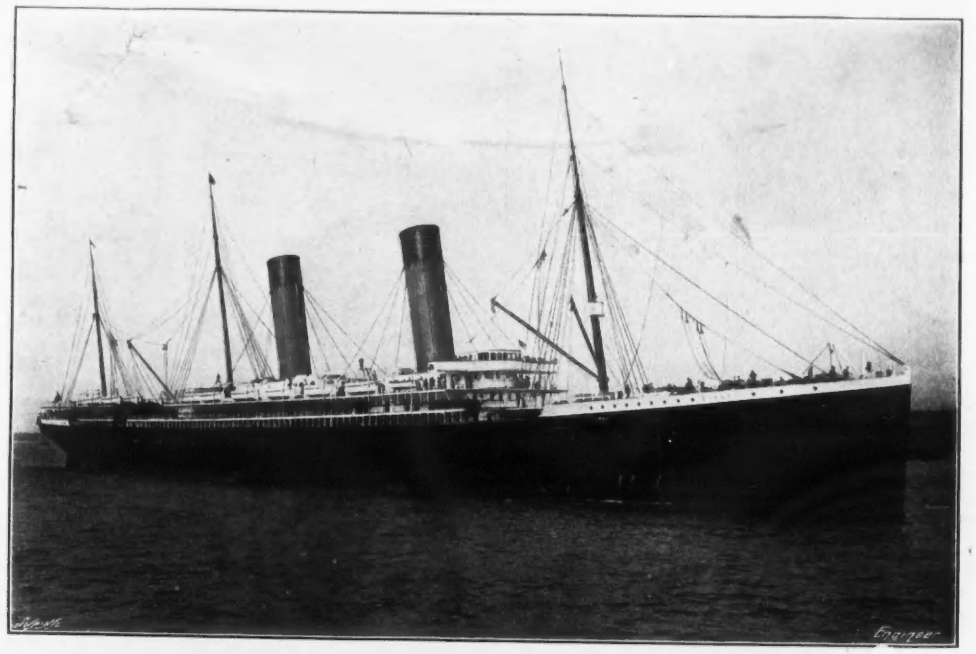


Fig. 7—THE OCEANIC, 1899

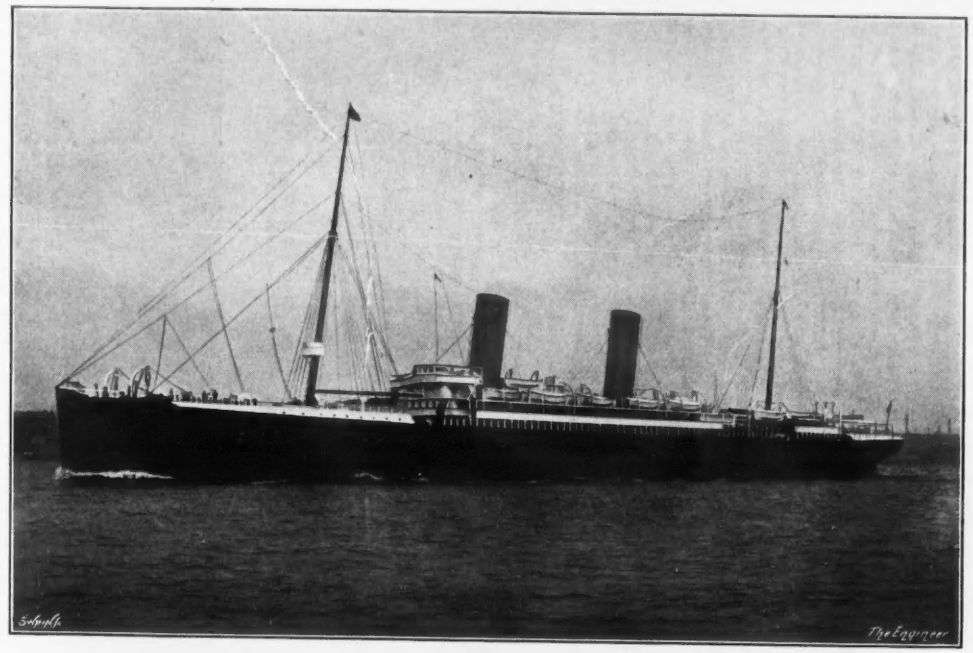


Fig. 8—THE MAJESTIC, 1889

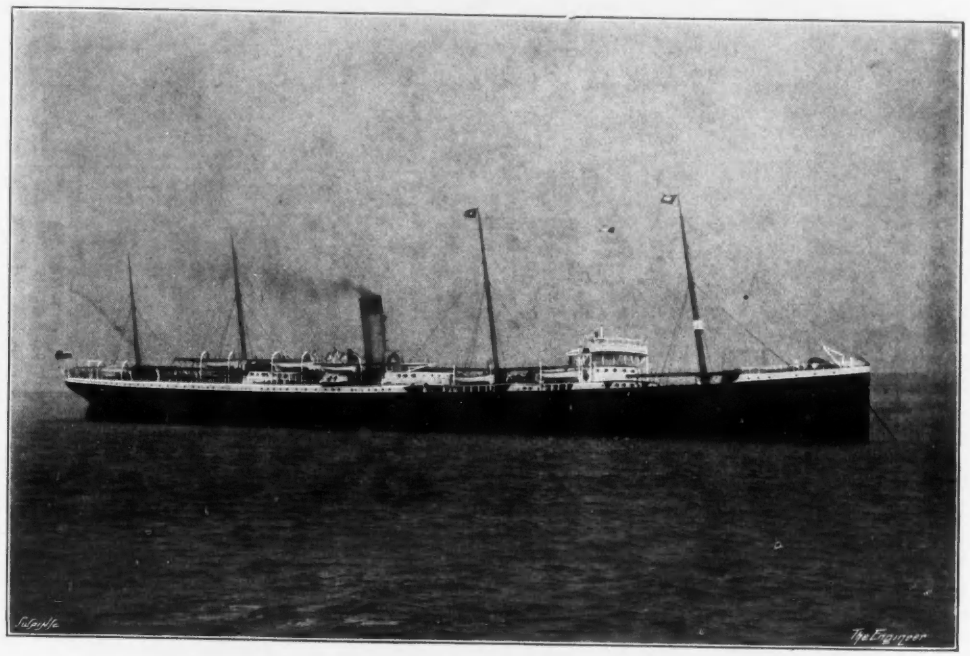


Fig. 9—THE RUNIC, 1899

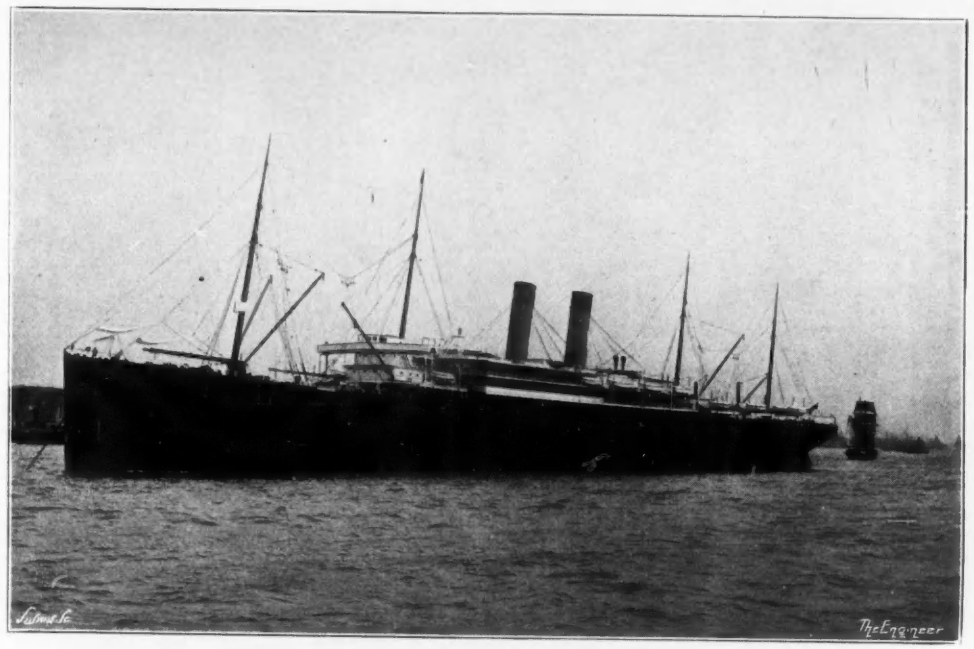


Fig. 10—THE CELTIC, 1901

Fig. 9—THE RUNIC, 1899

Fig. 10—THE CELTIC, 1901

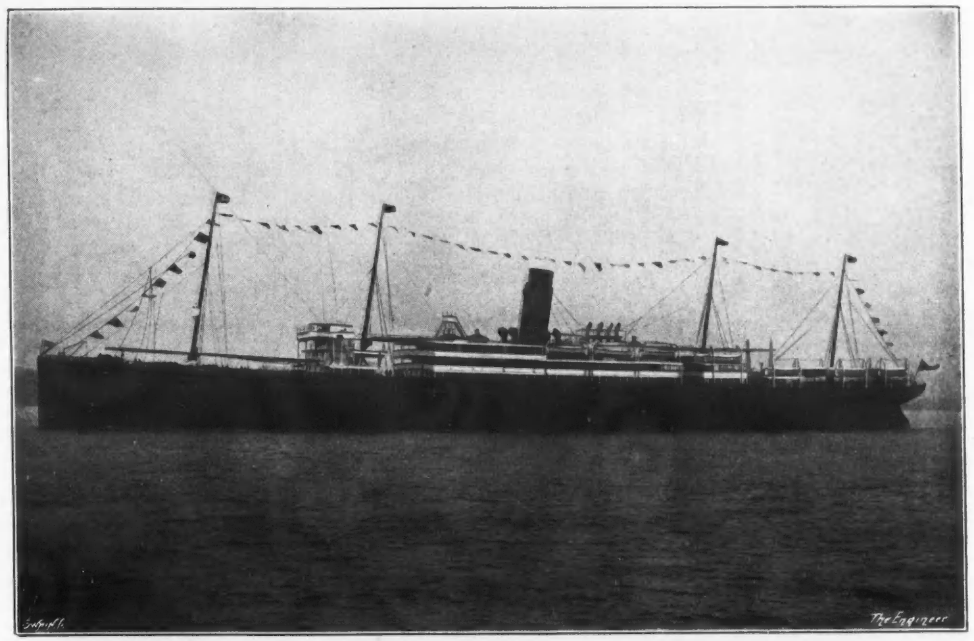


Fig. 11—THE ARABIC, 1903

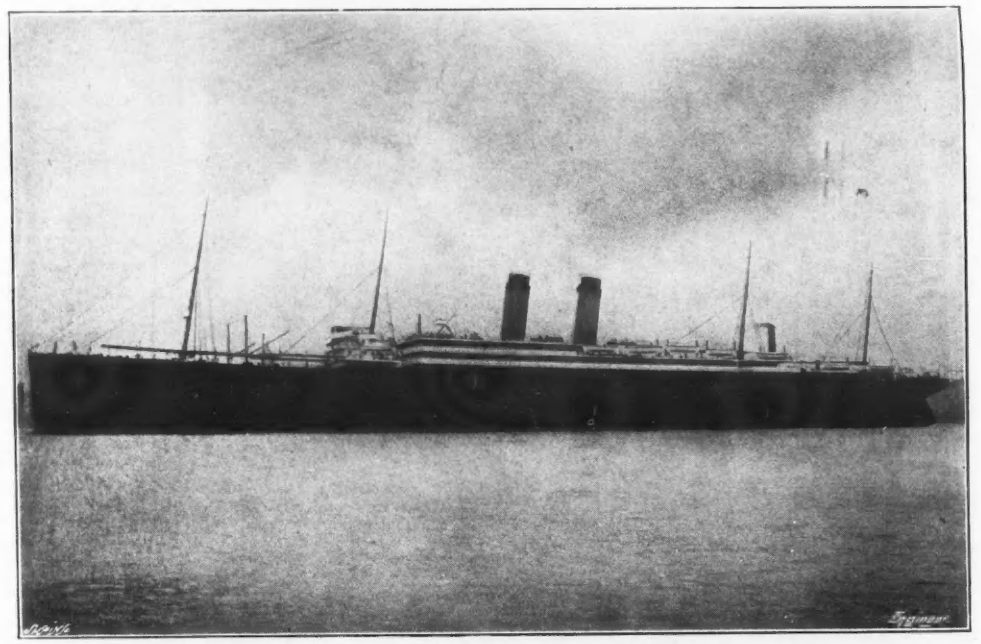


Fig. 12—THE BALTIC, 1904

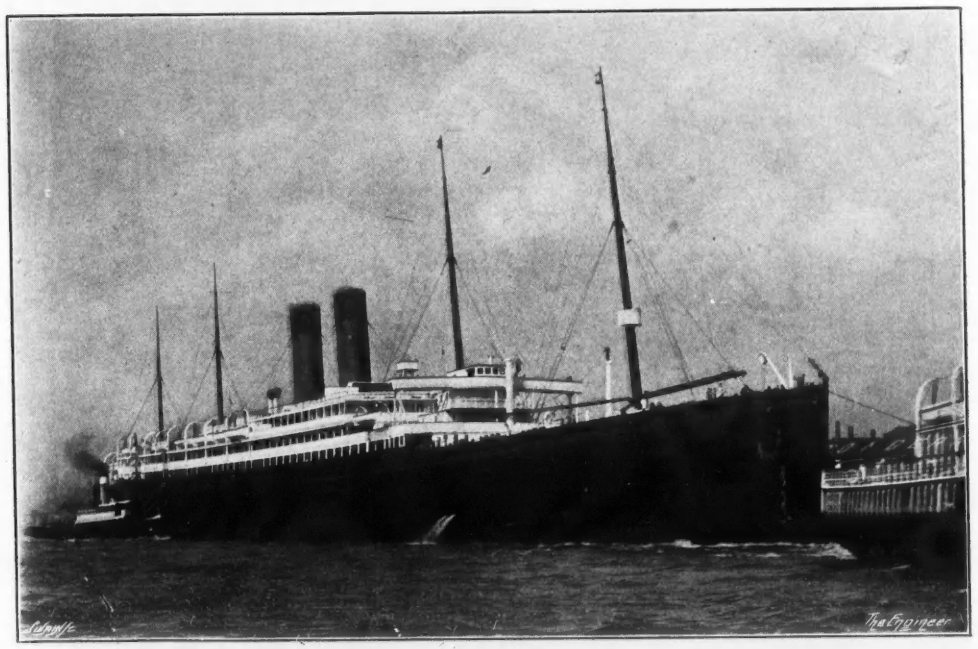


Fig. 13—THE ADRIATIC, 1907

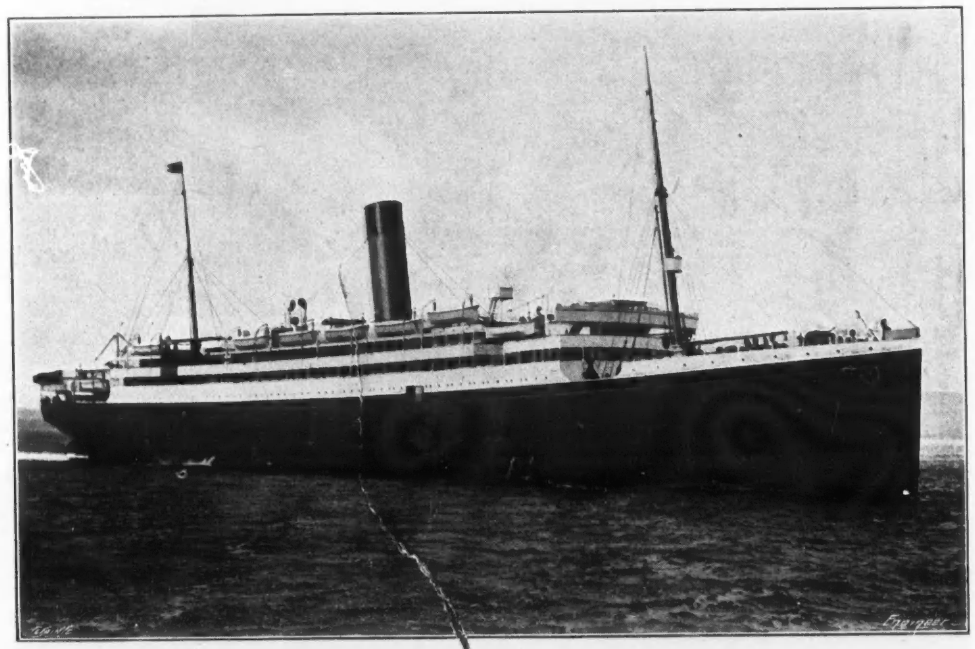


Fig. 14—THE LAURENTIC, 1909

565ft. 6in. long overall, and 550.4ft. long between perpendiculars; the moulded breadth is 67ft. and extreme breadth 67.35ft.; the depth of hold is 41.2ft., and depth from tonnage deck to ceiling 32.95ft. The load displacement is 20,420 tons, and the displacement on light draught—16ft. 8½in.—11,510 tons. They carry altogether 4035 tons of coal—1765 tons in the permanent bunkers and 2270 tons in the reserve bunkers. The piston engines have cylinders of the following dimensions:—

30in. + 46in. + 53in. + 53in. × 54in.

These drive three bladed propellers, 17ft. 6in. diameter, and with a pitch varying between 22ft. and 23ft. 6in. The blades have a surface of 76 square feet, and are of bronze, secured to a cast steel boss.

The low-pressure turbine driving the central propeller has the following dimensions:—

Expansion.	Rows of blades.	Height of blades.	Pitch of blades.
1st	10	33″	18″
2nd	10	5″	15/8″
3rd	10	7″	15/8″
4th	11	10″	21/8″
5th	11	10″	2 5/8″
6th	6	10″	2 17/32″

The turbine propeller has three blades and is of solid bronze, the diameter of the blades being 9ft. 6in., the pitch 9ft., and the blade surface 40 square feet. Steam is supplied to the engines at a pressure of 215 lb. per square inch by six double-ended boilers, 19ft. long by 15ft. 6in. diameter. There are thirty-six corrugated furnaces, 3ft. 9in. diameter, and the number of tubes in each boiler is 792, 7ft. 6¼in. long by 2¾in. outside diameter. The total heating surface is 29,298 square feet, and the grate area 777 square feet. The condensers of the Laurentic have a total cooling surface of 14,000 square feet. A distinctive feature of each of these two vessels is the single oval funnel. This is 118ft. 4in. high from the fire-bars and 129ft. 6in. above the keel. The outer casing of the funnel measures 17ft. 5in. by 13ft. 6in., and the inner casing 15ft. 6in. by 11ft. 9in. In the case of the Megantic the vessel is propelled by twin screws, driven by two sets of four-crank inverted quadruple expansion engines with cylinders as follows:—

29in. + 42in + 61in. + 87in. × 60in.

Although we are not in possession of any figures giving the comparative working of these sister ships, the fact that the builders, Harland and Wolff, are equipping the Olympic and Titanic with the combined system of engines and turbine and triple screws is significant.

The Laurentic carries a large quantity of cargo and a full complement of passengers, including 230 first class, 430 second class, and over 1000 third class. The hull is built on the cellular double-bottomed principle, the double bottom extending the whole length of the ship, and is specially strengthened under the engines to give still greater rigidity in the neighbourhood of the machinery. There are nine water-tight bulkheads. The vessel has two condensers, one on each side of the turbine, and the steam from the latter rises to a large rectangular opening in the sides of the condenser near the top. On the top of all is a large circular opening which takes steam, when the turbine is not in use, from the main engines. On each engine there is a large straining chamber with a change-over valve on the top. In one position this valve admits steam to the turbine and in the other it communicates direct with the condenser.

There are six cargo holds, and the bunkers are specially arranged to facilitate coaling. Special attention has been paid in the design of the ship to the requirements of shippers in the Canadian trade, large refrigerating chambers being provided both for provisions and cargo. The passenger accommodation in the Laurentic was devised on the most generous lines. The first-class state rooms are situated in a house on the lower promenade deck and also forward on the shelter deck, and there is a number of cabins *en suite* with separate lavatories and bath-rooms.

The first-class saloon—Fig. 19—on the middle deck is a handsome apartment which extends the whole width of the vessel, and has seating accommodation for 160 persons. It has a "well" arrangement overhead, with a balcony for the orchestra. This saloon is panelled and framed, finished flat white, and relieved with elaborate carving. The dado and furniture are of oak, and there is a parquetry floor. The first-class lounge on the upper promenade deck is in Louis XV. style, panelled in oak and with a parquetry floor. The reading room, Fig. 18, on the same deck is decorated in white after the Adams style, and also has a parquetry floor. The first-class smoking-room on the upper promenade deck is decorated with embossed leather, and carved framework round the windows. The furniture is of mahogany, and the floor india-rubber tiles. An electric passenger lift serves four decks.

The second-class accommodation is also remarkably luxurious. The state rooms are on the shelter deck, and the saloon on the middle deck is a very fine apartment, extending the whole width of the ship, and seating 262 persons. The second-class library is on the lower promenade deck, and the smoking-room on the upper promenade deck. They are both elegant rooms, tastefully decorated in polished hard wood. The cabins are also equipped in a quite exceptional manner. The third-class dining room, which is aft on the upper deck, is also a very fine room, extending the whole width of the ship. The promenading spaces on the ship are particularly attractive, the fullest advantage being taken of the ship's size to provide recreation for the passengers. The Laurentic is fitted up with the Marconi system of wireless telegraphy, and has submarine signalling apparatus.

The Megantic was launched on December 10th, 1908, and sailed on her first voyage in the Canadian service of this company on June 17th, 1909.

The Baltic and the new Adriatic—Fig. 13—are sister ships, one built in 1904 and the other as recently as 1907. They are the largest vessels in the fleet, their principal dimensions being:—

Length (overall)	725.9ft.
,, between perpendiculars	709.2ft.
Breadth (moulded)	75ft.
,, (overall)	75.5ft.
Depth (moulded)	56.75ft.
,, (hold)	52.65ft.
Displacement (light)	21,080 tons
,, (loaded)	40,790 ,,

They have each five continuous decks and eleven transverse water-tight bulkheads, and carry 5465 tons of water ballast. The engines of the Adriatic are of the same power. They are quadruple expansion inverted engines, with cylinders 35½in. + 51in. + 73½in. + 104in. × 63in. These drive manganese bronze twin screws, 20ft. 6in. diameter by 24ft. pitch, and the engines indicate collectively about 16,000 horse power. Steam at 210 lb. pressure per square inch is supplied by twelve boilers, eight double-ended, 19ft. 6in. by 15ft. 6in. diameter, and four single-ended, 11ft. by 15ft. 6in. These have sixty furnaces, a grate area of 1260 square feet, and heating surface of 52,152 square feet. The propelling machinery of the Baltic is similar to the Celtic and Cedric.

The Celtic and Cedric—Fig. 10—are twin-screw boats, and their leading particulars are appended:—

Length (overall)	697.5ft.
,, between perpendiculars	680.9ft.
Beam (moulded)	75ft.
,, (extreme)	75.35ft.
Depth (moulded)	48.2ft.
,, (hold)	44.1ft.

They have five continuous decks, and there are eleven bulkheads. The displacements are 19,700 tons with a draught of 21ft. 1in., and 37,000 with a loaded draught of 36ft. 8in., and the water ballast carried is 6080 tons. The engines of these two ships are quadruple expansion with cylinders 33in. + 47½in. + 68½in. + 98in. × 63in., and they indicate 13,000, and their average speed is 16½ knots. The propellers are 20ft. diameter by 24ft. 6in. pitch. There are eight double-ended boilers with 48 furnaces, and the heating surface is 41,680 square feet.

The Arabic—Fig. 11—is a twin-screw steamer with four continuous steel decks and ten water-tight bulkheads. The principal dimensions are:—

	Ft.	in.
Length (over all)	615	6
,, between perpendiculars	600	7
Breadth (moulded)	65	2
,, (extreme)	65	5
Depth (moulded)	51	3
,, (hold)	47	6
Displacement (light)	13,920 tons	
,, (loaded)	27,180 tons	
Water ballast	2830 tons	

The Arabic has two sets of quadruple expansion engines, with cylinders 30in. + 43in. + 63in. + 89in. × 60in., indicating 9800 horse-power. The propellers are 18ft. 6in. diameter by 23ft. 6in. pitch, and the average

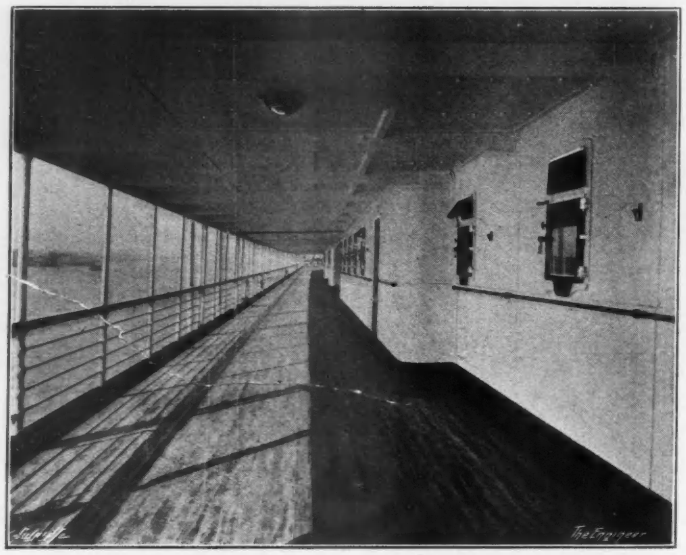


Fig. 15—PROMENADE DECK OF THE OCEANIC

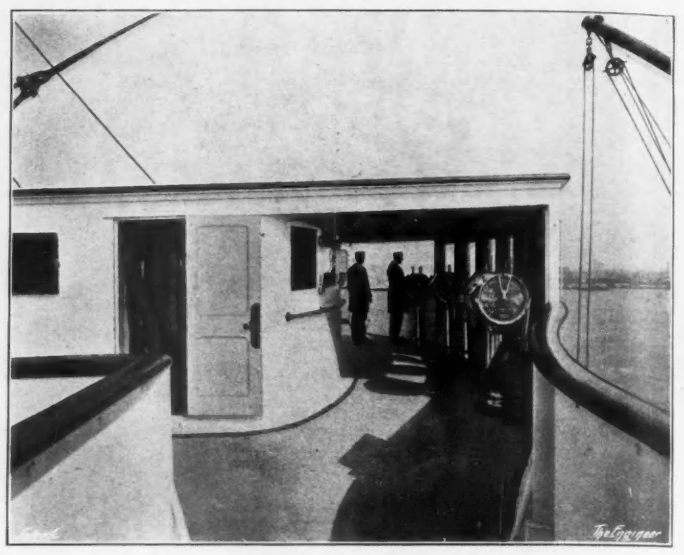


Fig. 16 BRIDGE OF THE OCEANIC

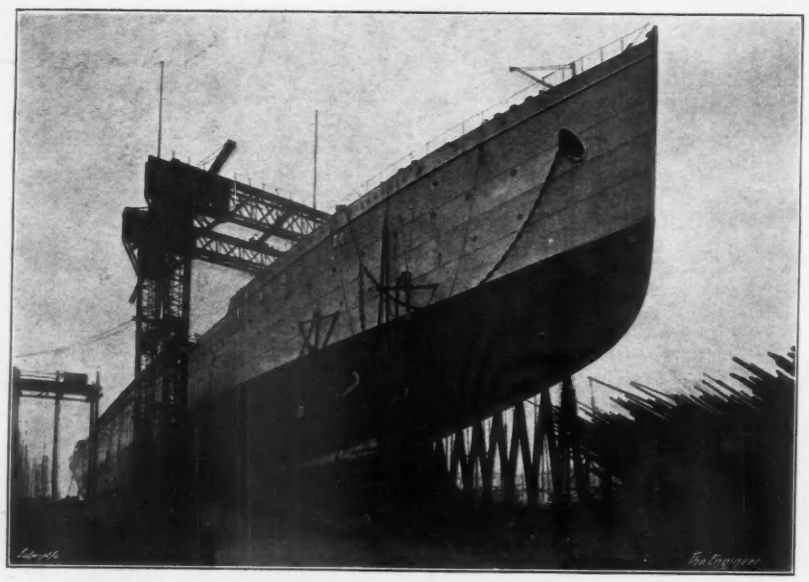


Fig. 17—OCEANIC ON THE STOCKS

Fig. 18—FIRST-CLASS, READING-ROOM—LAURENTIC

Fig. 19—FIRST-CLASS DINING SALOON—LAURENTIC

Fig. 20—SECOND-CLASS DINING SALOON—LAURENTIC

Fig. 21—SECOND-CLASS STATE ROOM—LAURENTIC

Fig. 22—FIRST-CLASS SALOON—ADRIATIC

Fig. 23—TURKISH BATH COOLING ROOM—ADRIATIC

speed 16 knots. She has eight boilers, four double-ended, 19ft. 10in. long by 14ft. 5in. diameter; and four single-ended, 11ft. long by 14ft. 5in. These have thirty-six furnaces, and a heating surface of 26,336 square feet. The boiler pressure is 214 lb. per square inch.

The Cymric is a twin-screw vessel 599ft.6in. long overall, ended 11ft. by 13ft. 9¼in. diameter, and four double-ended 19ft. 6in. long by 13ft. 9¼in. diameter. They have 33 furnaces and a heating surface of 21,106 square feet. The boiler pressure is 210 lb. per square inch.

The Cretic is the only vessel of the fleet not built by Harland and Wolff, Limited. She was built by Hawthorn, power at 78¼ revolutions. The speed of this vessel is over 15 knots. Her propellers are 18ft. 6in. diameter by 20ft. 3in. pitch. There are six boilers—three double-ended 16ft. 10in. long by 16ft. diameter, and three single-ended 10ft. 6in. long by 16ft. diameter. These have twenty-seven furnaces, 528ft. grate area, and

Fig. 24—THE GANTRY AND THE OLYMPIC—OCTOBER, 1909

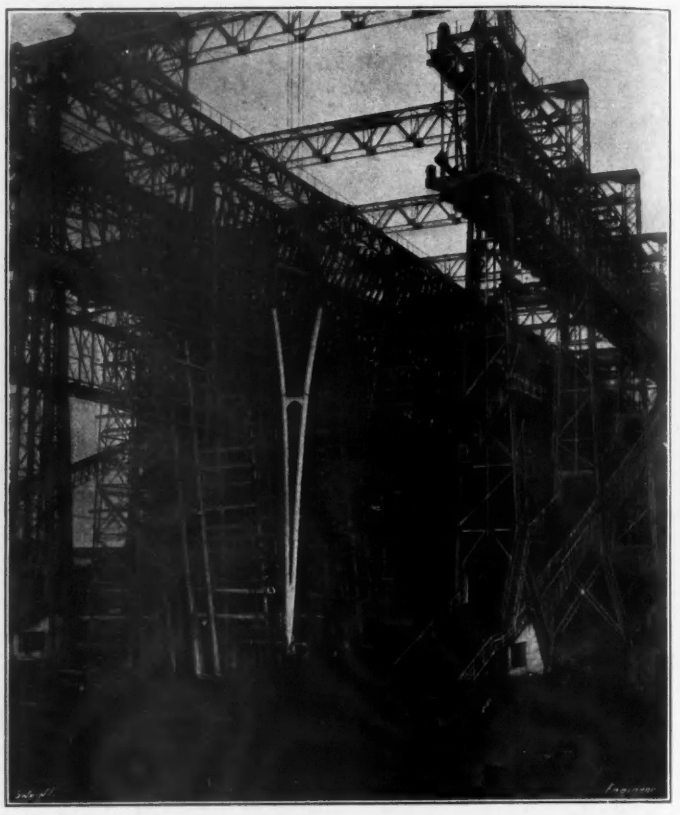


Fig. 25—LIFTING THE LAST FRAME INTO THE OLYMPIC—NOV. 23th, 1909

and 585ft. 5in. between perpendiculars. The breadth (moulded) is 64ft., and extreme 64.3ft.; depth (moulded), 41ft. 3in.; and depth of hold, 37ft. 9in. She has three continuous steel decks, and is divided by 10 bulkheads. Her displacements are, light, 11,300 tons, and loaded 24,230 tons, and she carries 2641 tons of water in ballast. Leslie and Co., Limited, in 1902. She is a twin-screw ship 601.75ft. long overall; 582ft. long between perpendiculars with a beam, moulded, 60ft. and extreme 60.3ft. Her depth, moulded, is 42.5ft. and the depth of hold is 38.33ft. The Cretic has three continuous steel decks and ten watertight bulkheads. Her displacement is 24,140 tons 21,723 square feet of heating surface, the working pressure being 200 lb. per square inch.

The Canopic is a twin-screw passenger steamer 593.75ft. long overall, 578.3ft. between perpendiculars. Her breadth moulded is 59ft., and overall 59.3ft., and the depth 40ft. moulded and 35.87ft. depth of hold. The

Fig. 26—THE OLYMPIC NEARLY FRAMED AND TITANIC BEGUN—NOV. 18th, 1909

The engines are two sets of quadruple expansion with cylinders 25½in. + 36½in. + 53in. + 75½in. × 54in., and give 7700 indicated horse-power, which suffices to drive her at an average speed of 15 knots. The propellers are 17ft. 2in. diameter and the pitch is 21ft. 9in. Of boilers there are seven, three being single-on a loaded draught of 32ft. 10½in., and she carries 5120 tons of water ballast. The engines, of which we give illustrations on page xiii., are two sets of triple-expansion type with cylinders 28in. + 47½in. + 80in. × 60in., and indicate normally 7800 horse-power, but on trial indicated a maximum of 9191 horse-Canopic has three continuous steel decks and twelve water-tight bulkheads. Her displacement, light, is 11,300 tons, and loaded to a draught of 31ft. 0½in. is 24,230 tons. She carries 4359 tons of water ballast, and has two sets of triple-expansion four-crank engines with cylinders 29½in. + 50in. + 58in. + 58in.

× 54in., which indicate 8500 horse-power and give the vessel a speed of 15½ knots. The propellers are 17ft. 6in. diameter by 22ft. 6in. pitch, and the boilers are six in number, three being double-ended 17ft. 10in. long by 16ft. 5in. diameter, and three single-ended 10ft. 6in. long by 16ft. 5in. diameter. These have thirty-six furnaces, 642ft. grate area, and 23,565 square feet of heating surface. The working pressure is 190 lb.

The Romanic is a twin-screw passenger boat 566ft. overall and 552.25ft. between perpendiculars. She has three steel decks and nine bulkheads. Her moulded beam is 59ft., and extreme 59.3ft., moulded depth 39.9ft., and depth of hold 35.9ft. She displaces 10,000 tons light and 20,550 tons loaded to a draught of 30ft. 6in., and carries 1765 tons of water ballast. Her boilers are similar to those of the Canopic, and her engines are of similar dimensions with the exception of the high-pressure cylinder, which is ½in. larger in diameter. The Romanic is a 15½-knot boat.

In the Australian freight and passenger service the group of five sister ships, Afric, Medic, Persic, Runic and Suevic—Fig. 9—built in 1899. These are all twin-screw ships, 565.6ft. long overall, and 550.2ft. between perpendiculars. They have a moulded beam of 63ft. and moulded depth 43.2ft., three steel decks, and ten bulkheads. The loaded displacement of the Afric, Medic, and Persic is 24,630 tons, and of the Runic and Suevic 24,950 tons. Quadruple expansion engines are fitted, the dimensions being 22in. + 31½in. + 46in. + 67in. × 51in. These give 4800 indicated horse-power, and with propellers 16ft. 3in. diameter by 20ft. 6in. pitch, propel the boats at an average speed of 13 knots. One single-ended and four double-ended boilers with 27 furnaces, 486 square feet of grate area, and heating surface 17,095 square feet, supply steam at 215 lb. pressure. These vessels carry only one class of passengers, and are claimed to be the largest sailing from the United Kingdom in the Australian trade fitted for the carriage of frozen mutton and dairy produce. In addition to these there are the five twin-screw freight steamers Georgic, Cevic, Cufic, Tropic, and Bovic.

The Georgic is 558ft. 7in. between perpendiculars, beam 60.37ft., loaded displacement 20,880 tons, and her water ballast capacity 4735 tons. This ship has three continuous steel decks, and is propelled by two sets of triple-expansion engines, with cylinders 24in. + 39½in. + 65½in. × 51in. The aggregate horse-power is 4800, the average speed 13 knots, and the size of the propellers 15ft. 10½in. diameter by 20ft. 6in. pitch.

The Cevic measures between perpendiculars 500ft., has a beam of 60ft. 3in., and is 38ft. deep. She has three steel decks and nine water-tight bulkheads, while her displacement is 17,270 tons. This ship is fitted with two sets of triple-expansion engines, 23½in. + 38½in. + 64in. × 48in. These give 4100 indicated horse-power, with screws 15ft. 9in. diameter, and pitch 20ft. 6in., propel the boat at an average speed of 13 knots. She has four boilers, two double-ended and two single-ended, with eighteen furnaces, and 12,760 square feet of heating surface. The boiler pressure is 175 lb.

The steamers Cufic and Tropic are 475ft. 9in. long between perpendiculars, 55ft. beam, and 36ft. deep. They have three steel decks and seven water-tight bulkheads, their displacement loaded to a depth of 28ft. 11¼in. being 16,755 tons. Both boats carry water ballast to the extent of 1494 tons. They have each two sets of triple-expansion engines with cylinders 19in. + 31in. + 52in. × 48in., which indicate

DIAGRAM SHOWING COMPARATIVE SIZES OF VARIOUS TYPES OF WHITE STAR STEAMERS FROM 1871 TO THE PRESENT TIME

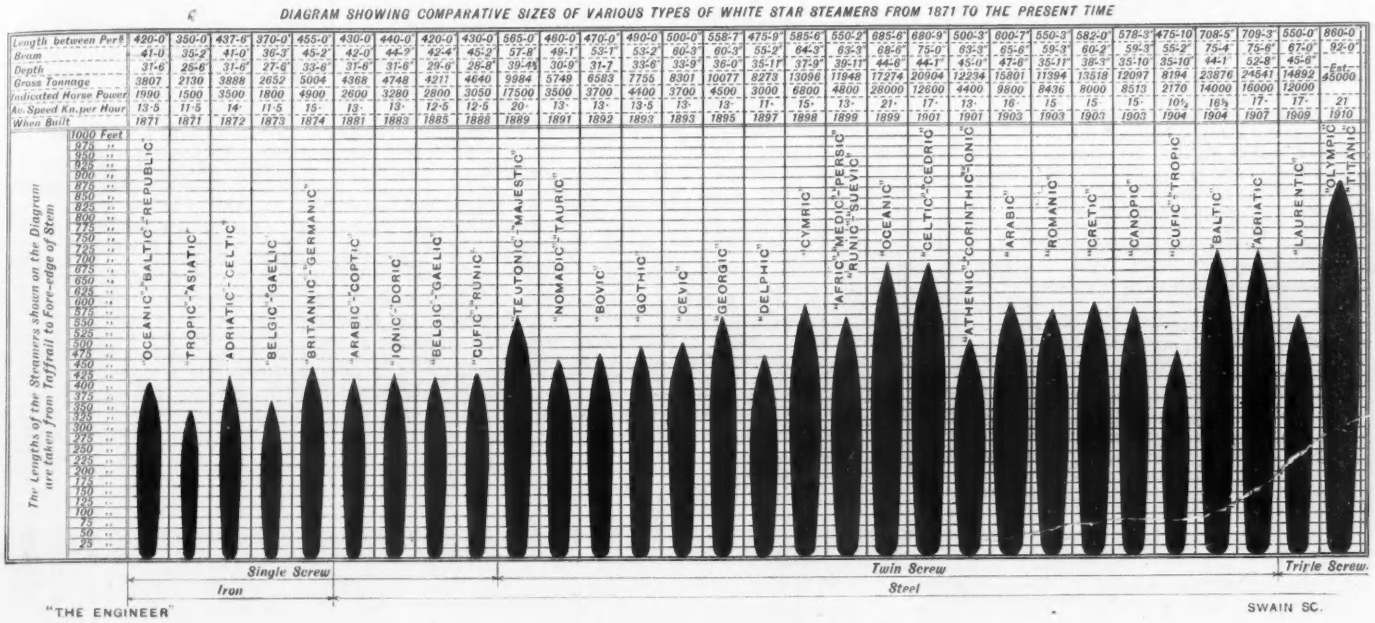


Fig. 27—PROGRESS OF WHITE STAR STEAMERS

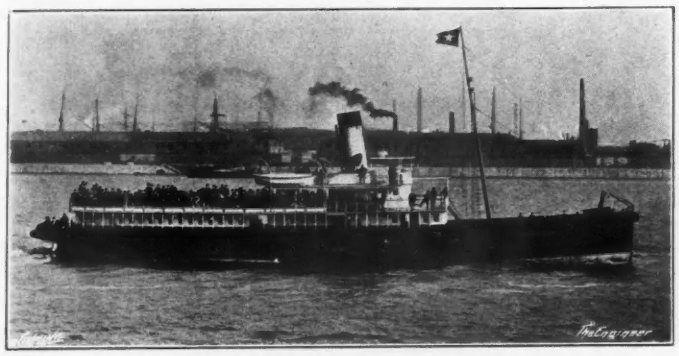


Fig. 28—WHITE STAR TENDER MAGNETIC

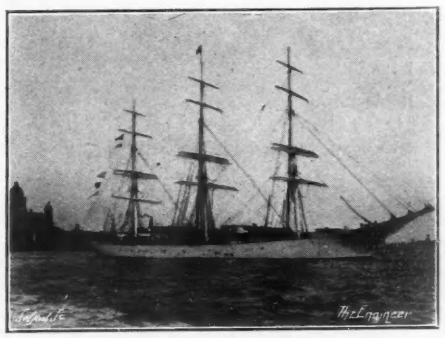
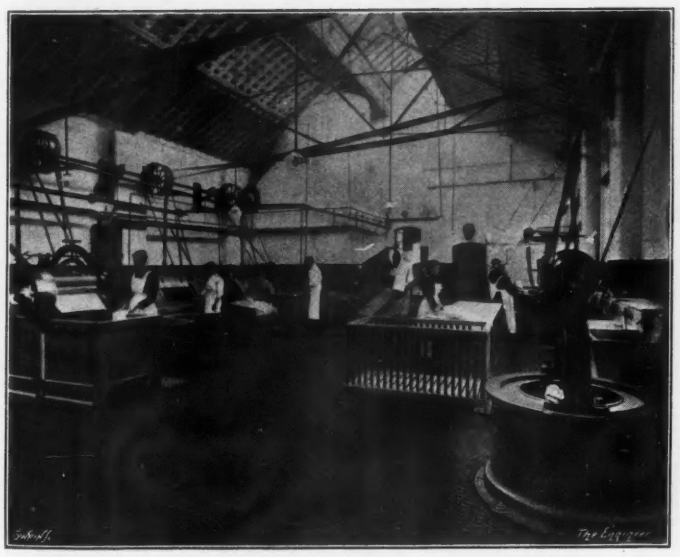


Fig. 29—CADET SHIP MERSEY



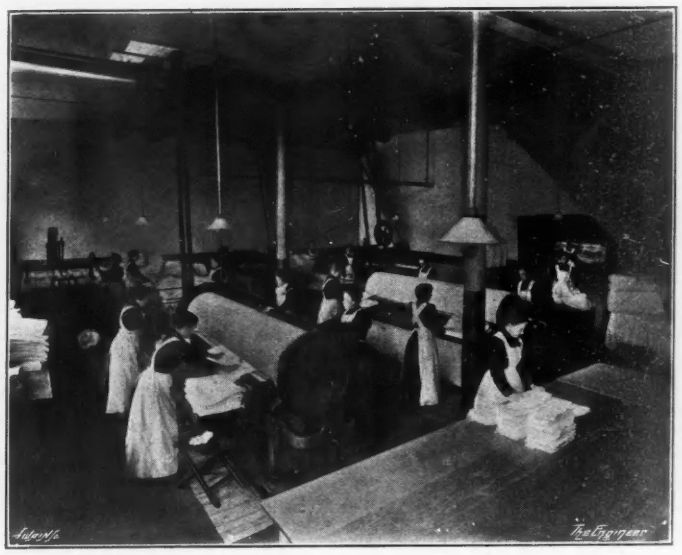


Fig. 30—THE LAUNDRY AT BOOTLE

collectively 2350 horse-power and propel the boat at a speed of 11 knots with screws 14ft. 9in. diameter and 18ft. 9in. pitch. They have two double-ended boilers, working at 176 lb. pressure per square inch, and with a total heating surface of 8441 square feet.

The Bovic is the smallest boat engaged in this service, being 470ft. long between perpendiculars, 53ft. beam, and 35ft. deep. She has three steel decks and nine water-tight bulkheads, and her displacement, when loaded, is 14,120 tons; she carries 1214 tons of water in ballast. The power is furnished by two sets of triple-expansion engines 22½in. + 36½in. + 60in. × 48in., which indicate 3700 horse-power and propel the vessel at a 13-knot speed. There are four boilers, two double and two single-ended, and these have eighteen furnaces and 11,544 square feet of heating surface, the steam pressure being 176 lb. per square inch.

We come next to the Athenic, Corinthic, and Ionic, three twin-screw passenger steamers built by Harland and Wolff in 1901. These three ships are the three largest vessels engaged in the New Zealand service which is run in conjunction with the Shaw, Savill and Albion line. The chief dimensions of these sister ships are as follows:—

Length (overall)	515ft.
,, between perpendicular	500ft. 3in.
Breadth (moulded)	63ft.
,, (extreme)	63ft. 3in.
Depth (moulded)	48ft. 4in.
,, (hold)	45ft.

They have four continuous steel decks, and are divided into twelve water-tight compartments by eleven bulkheads. They displace, when loaded to a depth of 33ft. 1in., 22,970 tons, and carry 1955 tons of water ballast. Power is supplied by two sets of quadruple expansion engines, 22in. + 31½in. + 46in. + 67in. × 48in., and have twin screws, 16in. diameter by 19in. pitch. These engines indicate collectively 4800 horse-power, and the ships have a speed of 13 knots. Two single-ended and three double ended boilers provide steam at 215 lb. pressure. These have a grate area of 435 square feet, heating surface 15,196 square feet, and twenty-four furnaces.

The Delphic is a smaller cargo boat in the same service by the same builders. She is 475ft. 9in. long between perpendiculars, 55ft. beam, and 40ft. 4in. deep, her displacement (loaded) being 16,850 tons, and she carries 1522 tons of water ballast. The machinery consists of two sets of triple-expansion engines 19in. + 31in. + 52in. × 48in. stroke. The propellers are 14ft. 9in. diameter and 18ft. pitch, and the total indicated horse-power of the engines is 2900. The average speed of the ship is 12 knots. She has three boilers, one single and the other two double-ended, with fifteen furnaces and a heating surface of 10,600 square feet.

The company owns three tenders, the largest of which is the well-known Magnetic—Fig. 28—of Liverpool. This boat is 170ft. 5in. long between perpendiculars, 32ft. moulded beam, and has 15ft. depth of hold. She has two steel decks, and her twin screws are driven by two sets of triple-expansion engines with cylinders 17in. + 27in. + 43in. × 28in. The indicated horse-power of the engines is 1120; the screws are 10ft. diameter by 16ft. pitch, and the average speed of the boat 13¼ knots. Steam is generated in two single-ended boilers 10ft. 3in. long and 13ft. diameter. This tender and the smaller one, Pontic, were both built by Harland and Wolff. At Cherbourg the company has a paddle tender called the Gallic, built by John Scott and Co., Kinghorn. She is 150ft. long by 28ft. 2in. beam, and is propelled by compound engines 22in. + 40in. × 48in. The paddle wheels are 16ft. 8in. diameter, and steam is supplied by two single-ended boilers at 110 lb. pressure per square inch.

Owing to the ocean-carrying trade having been largely transferred in recent years from sailing vessels to steamers, and by reason of the lack of opportunities for training future officers on steamships, the White Star Line decided a few years ago to remedy the deficiency by offering to educate cadets as apprentices on board a first-class sailing vessel of a size suitable for boys to handle. Under the commander there is an efficient nautical and educational staff, by whom the cadets are carefully and regularly exercised and instructed. In addition to having their general education completed, the boys are taught the special subjects required to qualify them for their profession. To carry on this excellent scheme Messrs. Ismay, Imrie and Co. commissioned the Clyde-built clipper ship Mersey—of which we give an illustration in Fig. 29. The Mersey is 271ft. long by 39ft. beam, 1829 tons gross register, ship-rigged and classed 100 A1 at Lloyd's. She is fitted throughout with electric light, and trades to Australia, or such other parts of the world as circumstances render desirable. About sixty boys are carried, preference being given to those who have had preliminary training on the Conway and Worcester. The Board of Trade has interested itself in the scheme, and has issued special regulations whereby cadets who have had four years' instruction on an approved training ship may sit for an examination for a certificate as second mate, and after obtaining this certificate and serving in vessels satisfying certain requirements, may be allowed to sit for examination for certificates as first mate and master. The boys are divided into three watches of twenty, each being in charge of a cadet captain chosen for his general fitness. These cadet captains, for the purpose of cultivating discipline, live in a separate room. After obtaining their second mate's certificates the cadets will have the preference for appointments as junior officers in the steamers of the White Star, Leyland, Dominion and Atlantic Transport Lines. In addition to undergoing a course of studies suitable to their calling, the cadets work the ship. Although carrying cargo, and worked in a thorough-going manner as a trader, the primary purpose of the owners is the patriotic one of training British officers for the British mercantile marine. The Mersey has recently completed her second voyage as a training ship, when she arrived in London on May 30th last.

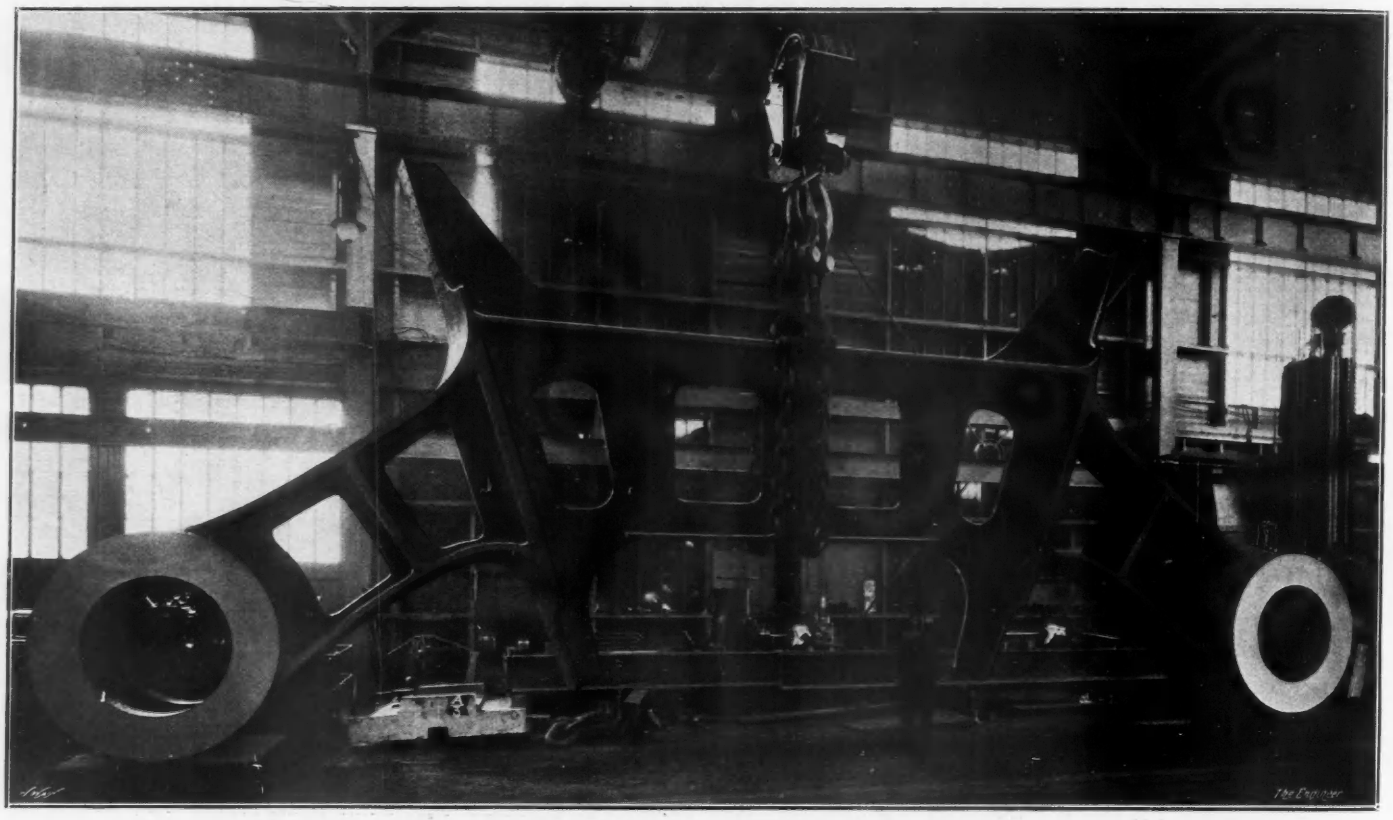


Fig. 31—FORWARD SHAFT BRACKETS OF THE TITANIC

OLYMPIC AND TITANIC.

We have now passed in review the most notable vessels of the White Star Line, but it remains—before saying a few words about the progress of marine engineering as developed by Ismay, Imrie and Co.—to touch upon the Titanic and Olympic, the two largest vessels ever built. They are still, as our readers are aware, as yet on the stocks, but there is every probability that one at least—the Olympic—will be launched in October next. Indeed, so precise are the arrangements made by her builders that the day—the 20th—and even the hour, of her launch have been settled; and with the knowledge that Mr. Carlisle, who has the arrangements of such huge details in his hands, has never been at fault yet, there is no reason to doubt that the event will take place at the moment he foretells. Unfortunately, at the present time the White Star Company is unwilling to permit anything like a complete description of these vessels to be written, but with the help of the excellent series of progress photographs we are enabled to reproduce, on page viii. and on a special plate, a good idea of the general construction and the progress that has been already made will be gained. The owners do not wish even the exact length given, but we may say that it is in the neighbourhood of 860ft., whilst the displacement will be about 45,000 tons. The engines, presumably as a result of the tests of the Laurentic and Megantic, will be on the combined system, the vessels being propelled by three screws in a similar manner to the Laurentic—that is to say, with two reciprocating engines on the wings exhausting to a low-pressure turbine on the central shaft. On pages xiv. and xv. we give views of parts of the machinery of the Olympic and two of the huge patterns of the turbine casing.

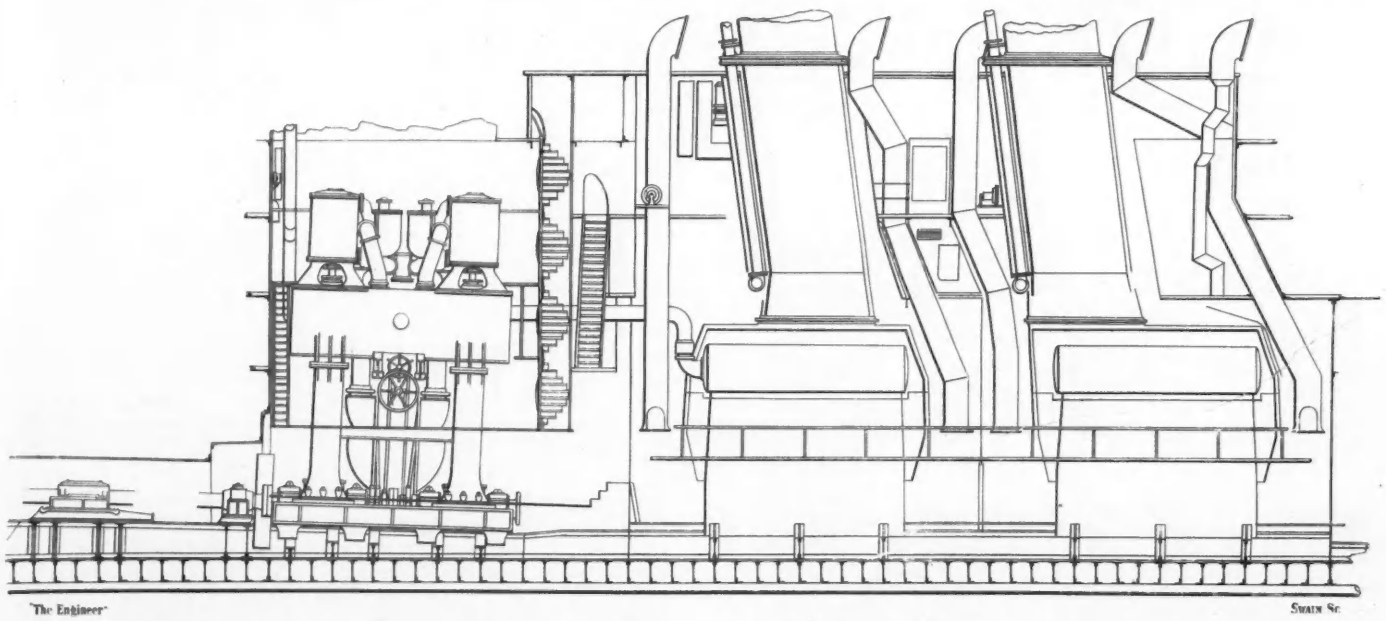
Before the construction of these enormous liners could be undertaken, preparations on the grand scale had to be made at the builders' yard. These involved the preparation of two berths big enough for vessels of such length and weight and the erection of a magnificent gantry—undoubtedly the largest thing of its kind in the world. In the special Supplement on Harland and Wolff's works, which we printed about this time last year, we gave a complete account of this gantry, but it is so bound up with the Olympic and Titanic that a short description of it must be given here. Originally on its site there were four berths spanned by three large hydraulic gantries. One slip was left where it was, and the two other gantries were lifted up bodily on to rails and transported sideways until they covered this slip, which now has the use of all three. This cleared the ground for the new slips for the leviathans. First of all a bed sufficiently strong to take their enormous weight had to be constructed. For this purpose the ground was heavily piled, and then a concrete floor reaching in places as much as 4ft. 6in. thick was laid on and around the piles in such a manner that the latter take the load. This floor is suitably inclined to ensure a steady launch, the upper part at about ⅜in. to the foot, the lower near the water about ¼in. Covering this floor is the great gantry, which figures so prominently in all the engravings. It was designed by Harland and Wolff, Limited, and constructed by Sir Wm. Arrol and Co., Limited, all the electric cranes being supplied by Stothert and Pitt. The space covered is more than 850ft. long by 270ft. broad, whilst the height is 180ft. The structure consists broadly of three rows of eleven steel pillars, 80ft. apart, the space between the rows being 120ft. On the tops of these columns run three longitudinal lattice girders, with cross girders bracing the whole framework together. On the centre longitudinal girder runs a great Titan crane, which can lift a load of three tons at 135ft. radius. Lower down on the columns there are more lattice girders—these no less than 30ft. deep—which carry three travelling frames over each of the two bays, besides supporting a number of walking jib cranes—ten in all. Each of the frames—which are movable longitudinally—is provided with two ten-ton travelling cranes, working transversely. Each frame has, moreover, two lifting eyes for 40 tons each.

In all there are no less than twenty-three crane hooks in this gantry, and the motors total something like 1500 horse-power. Besides bringing material to the ships under construction, these cranes support the hydraulic riveting machines by which the bulk of the work is being done. At the end of each slip a cofferdam of piles is built to keep the water out till the vessels are ready to be launched. It is then removed to give the ship a clear

run into the water. One of the pictures, dated January 1st, 1909, in the Supplement, gives an admirable idea of the complete gantry, and shows the coffer-dam very clearly. In it the first stage in the construction of the Olympic is seen, the keel plate having just been laid. Another view made on the same day is taken from the opposite end of the gantry. A better idea of the magnitude of the structure is gained from these two pictures than from those in which the vessels are more advanced. Another pair of reproductions of photographs taken on February 18th, 1909, show the keel and vertical keel plate of the Olympic from both ends. One of these views exhibit the method of supporting the floor of the double bottom very clearly, and gives an admirable idea of the design of these vital parts of the structure. The two remaining larger pictures in the Supplement are dated July 2nd and July 30th, and show how quickly the work at this stage proceeds. In the first much of the top of the tank has been completed, and the beams for the wing tanks are seen in place. The method of supporting the structure on each stage by the addition of wooden struts is well seen in these pictures. In the view dated July 30th a further stage is reached, a commencement having been made on the erection of the frames at the stern. These shows the supplementary towers built at the end of the gantry, and the others show the condition of the vessel in November last. By then the Olympic was nearly framed, and early stages in the construction of the Titanic had begun. On November 20th the last frame was lifted into the Olympic, as one of the views in question shows.

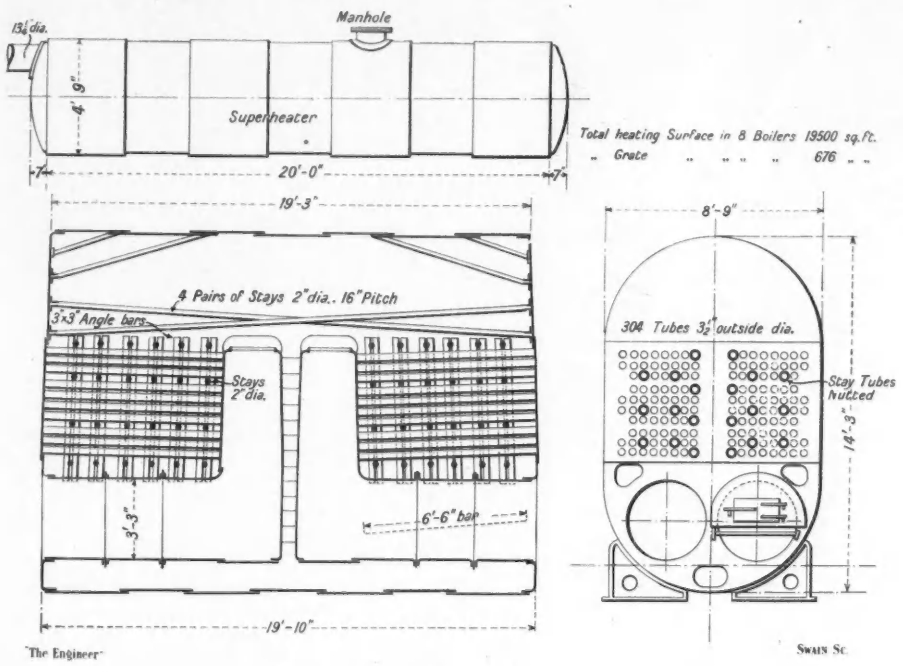
Since then the most interesting work has been the building in of the bow and sternframes, huge steel castings supplied by the Darlington Forge Company, which also made the great shaft brackets. All these parts were illustrated and described in our issue of December 17th last, and illustrations are given on pages x. and xvi.

From the foregoing particulars of the White Star fleet, a good idea will be formed by the reader of the remarkable



"The Engineer" SWAIN Sc

Fig. 32—ENGINES AND BOILERS OF THE BRITANNIC, 1874



"The Engineer" SWAIN Sc

Fig. 33—BOILERS OF THE BRITANNIC

can be seen at the far end of this view. Incidentally, this picture shows very clearly the long ramps up the gantry by which workmen ascend.

Turning now to the smaller views in the Supplement, one dated April 15th takes us back a few months, and gives us a bird's-eye view from the top of the gantry. From it a very clear idea of the general appearance of the tank is obtained. The brackets for the side tanks are seen at the sides ready to be put into position. In these two ships the double bottom is more extensive than usual, being carried round the bilge. This double bottom, as most of our readers are aware, serves several purposes. It provides space for a large quantity of water ballast, thereby giving the vessel great stability, and while contributing to the stiffness of the hull generally, forms an important element of safety in the event of the vessel grounding. The next view, dated July 30th, shows more in detail the framing at the after end, just seen in a larger picture of the same date already referred to. When it is remembered that the gantry is some 180ft. high, the enormous size of the frames will be understood. The last two photographs reproduced were taken on October 18th, 1909. They were both taken looking aft, and show that the vessel—the Olympic—was more than half-framed by that date. Of the three illustrations on page viii., the first strides which have been made, not only in marine engineering during less than half a century, but also of the magnitude of the organisation which is necessary to maintain the numerous services efficiently and profitably from the owners' point of view. The building of huge liners at the present day involves no insuperable difficulties; but to run such ships at a profit to the owners is by no means easy. The public are largely indebted to the White Star Line for many improvements in the means provided for ocean travelling. Amongst these may be mentioned the following:—Improved proportions of ships; the placing of the saloon and passenger accommodation amidships; self-acting water-tight doors; improved sub-division of the hulls by bulkheads; overlapping twin propellers; and last of all, but not the least, the adoption of the combined reciprocating engines and turbine principle of propulsion.

WHITE STAR WORKS, LIVERPOOL.

These works were originally started in 1873 in Neptune-street, Liverpool, and were removed to their present situation in Strand-road, Bootle, in 1886. They find employment in all for some 400 hands, and are engaged exclusively on carrying out alterations and repairs of the company's ships. The building is a substantial one of brick, and occupies about 440 square yards. In the basement is the men's dining-room, tool stores, bond and victualling stores. On the ground floor are the general offices, the superintending engineer's offices, and victualling superintendent's offices, the brass foundry, blacksmiths' shops, general, victualling and plumbers' stores, boiler-house, fitting shop, and paint store. On the first floor is the drawing-office, opticians' room, joiners' shop, fitting shop, copper shop, upholsterers' shop, and a laundry—Fig. 30—capable of dealing with 3000 linen articles per day. The latter comprises a sorting room, wash-house, drying room and calender room, linen repair and store rooms. The second floor contains patternmakers' stores, brass shop, sheet metal workers' shop, japanning shop, brazing shop, silversmiths' shop, upholsterers' store, sail makers' shop, and accommodation for the janitor. Steam for the whole works is supplied by two Lancashire boilers. These drive the laundry machinery, the main 50 horse-power engine by Messrs. Pollock and Macnab, and two sets of direct-coupled electric light engines. Amongst the most important machine tools are a long 24in. lathe by Davies and Primrose; a 7ft. 6in. radial drilling machine and 2ft. vertical slotting machine, both by Pollock and Macnab; a horizontal planing machine, 11ft. stroke, by Oldham and Richards, which was originally driven by means of a rack and pinion, but has since been converted into a screw driven machine, and an 8ft. face-plate lathe. In the upper fitting shop is a 3in. turret lathe by Alfred Herbert, Limited, and in the blacksmiths' shop are two steam hammers by Davies and Primrose. In the laundry the machinery includes Bradfords' calenders, rotary washing machines, and hydro extractors. In addition to the above works there is a boiler shop at Bankhall, Liverpool. This is electrically driven by motors off the Corporation supply system; and there are also workshops at Canada Dock, adjacent to the ships' berths.

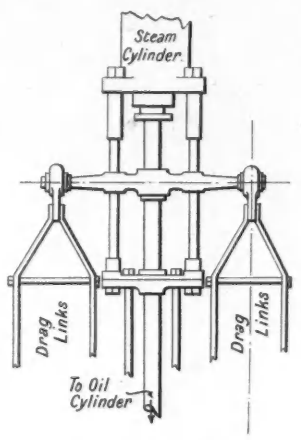


Fig. 34—REVERSING GEAR

DEVELOPMENT OF THE MARINE ENGINE.

The history of the marine engine is inextricably bound up with that of Britain's great shipping companies, because the united purses of numbers of individuals are

required to supply the very large capital sums expended on the construction of ships and machinery which never reach finality in design or dimensions. In the present day we have magnificent German and French liners, but

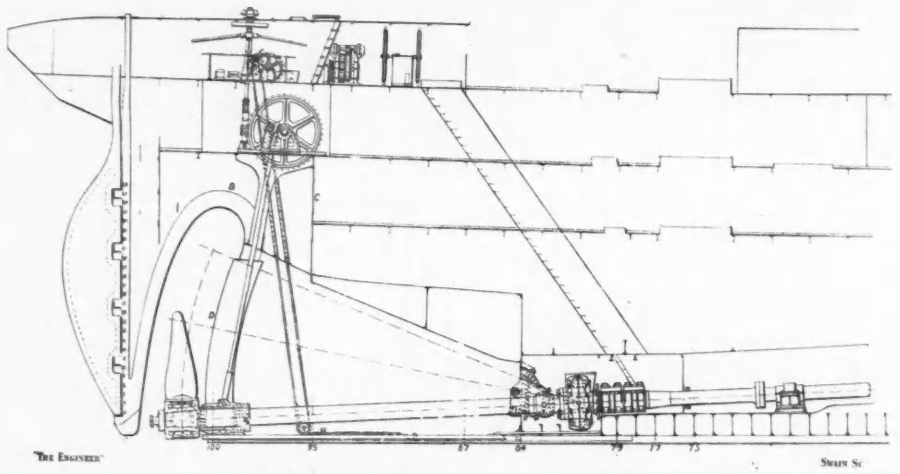


Fig. 35—LIFTING PROPELLER OF THE BRITANNIC

their owners and designers and builders have simply followed in the footsteps of the men of this nation; and to this moment, in spite of all the boasting of Germany, Great Britain and Ireland lead the van. We have advanced continuously, and no other nation has ventured on such flights as the Mauretania and her sister, the Lusitania.

The marine engine has grown continuously from small beginnings until it now represents the most powerful machinery in the world. Unceasing demands have been made on engineers, and they have always responded, until at last it seems that there is no limit The shipowner has only to ask and to have. The White Star Company's progress constitutes an interesting chapter in the history of marine engineering. "The line" came into existence, as we have explained above, more than fifty years ago, with a small fleet of sailing ships, and it was not until 1870—that is to say, nearly forty years ago—that the company possessed a steamer. In the preceding pages will be found an account of the earlier days of the company and its work. The "White Star" found the marine engine far advanced on the road to that perfection which it subsequently attained. It will not be out of place to say here something of the position of marine engineering, and of the way in which it had attained that position in 1870.

By, we think, common consent, the credit of introducing the compound engine into ships on a commercial basis is due to the late John Elder, in the year 1854, when Messrs. Randolph Elder and Company, of Glasgow, put compound engines into the s.s. Brandon. Two years later they put compound engines into the paddle steamers Valparaiso and Inca. They were all three very successful, although the pressure did not exceed 30 lb. on the square inch. Before that date Messrs. Rowan had produced the engines of the Thetis, which may be regarded as the forerunner of the modern triple-expansion engine. So far, however, as we can ascertain, the first compound engines to find permanent favour were used by the P. and O. Company. These were the engines of the Carnatic. The ship was built by Messrs. Samuda at Deptford. The engines were by Messrs. Humphrys and Tennant. They were tandem vertical engines of very simple design, with the air pumps driven direct by rods from the low-pressure piston, a method of construction retained to the last by the firm. The cylinders were 43in. + 96in. × 3ft. The water was sent through the surface condensers by a centrifugal pump. The pressure was only 26 lb. above the atmosphere, yet the consumption is stated to have been well under 2 lb. per indicated horse-power per hour. Steam was made by Lamb and Summers sheet flue boilers; and the steam was moderately superheated at the root of the chimney. The engines were made in 1865. The Carnatic had a trial trip speed of 13.9 knots. The engines were of beautiful workmanship, and to this, no doubt, much of their success was due. Next came another P. and O. boat, the Mooltan, with very similar vertical tandem engines, with cylinders 43in. + 96in. × 36in. They had a Halls surface condenser, containing about as much surface as the boilers, a centrifugal circulating pump, and Lamb's superheaters. These engines were built somewhere about 1864. But the pressure did not exceed 30 lb. From that time onward the compound system came more and more into favour, a result largely due to the improvements introduced in the manufacture of iron plates, which rendered the introduction of higher and higher pressures in boilers possible. Improved machine tools facilitated the production of large engines and reduced the chances of breakdowns. The position was one of excellent opportunity for any firm who would act with energy and courage. The Oceanic Steam Navigation Company possessed both, and gave the order for the Oceanic, which was built by Harland and Wolff, launched on the 27th of August, 1870, and sailed on her first voyage to New York under the White Star flag on the 2nd of March, 1871. She was followed in quick succession by the Baltic, Republic, Adriatic, and Celtic, forming a fleet equal in speed and surpassing in accommodation any ships then afloat. The Adriatic is not to be confounded with a predecessor of the same name, a paddle steamer built in the United States. The engines of this ship were fitted with a very peculiar cam valve gear, which gave much trouble. On her first voyage to this country the commander wished to call at Cork, but the chief engineer refused to stop his engines, because, he said, "he doubted if he could ever start them again," and the ship came on to Liverpool.

The next important advance was the construction of the Britannic and Germanic in 1874-5. These vessels were

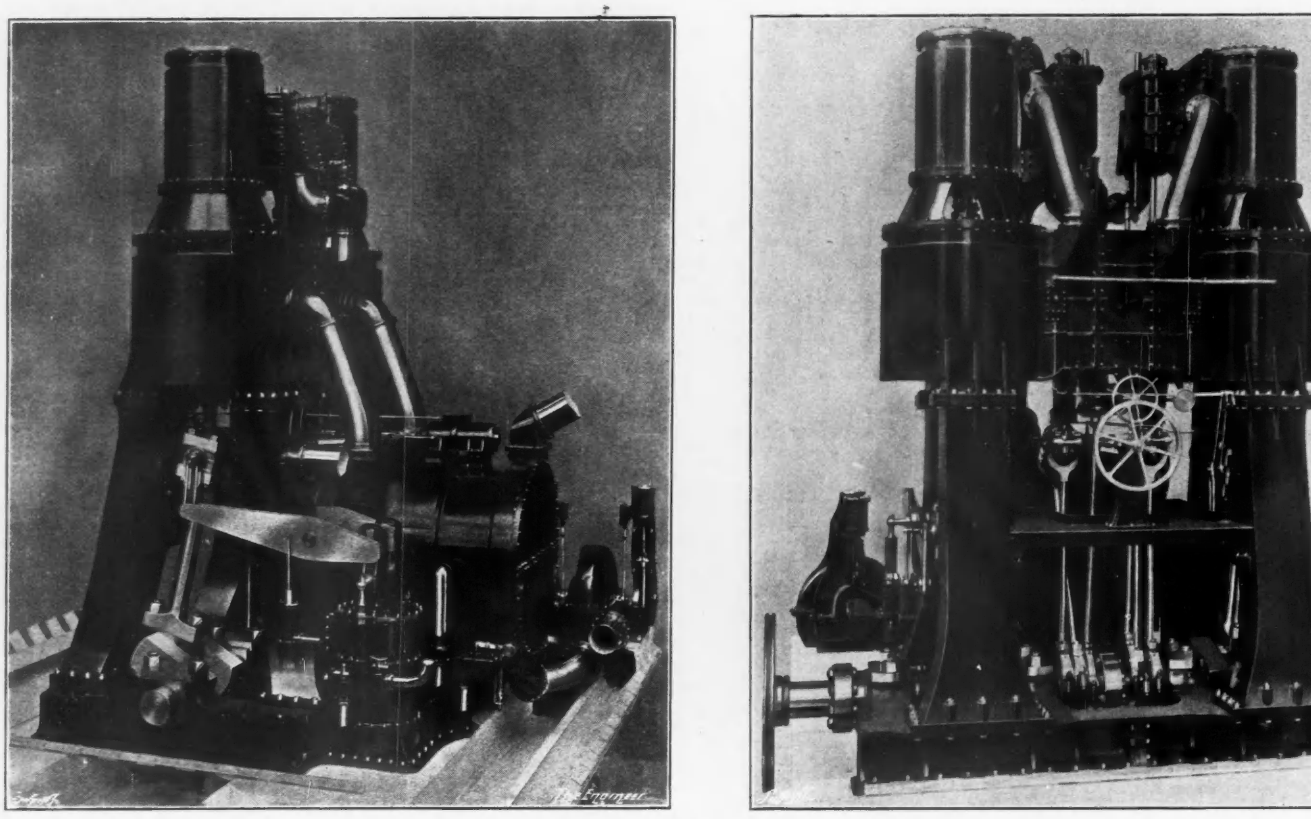


Fig. 36—ENGINES OF THE BRITANNIC—MODEL

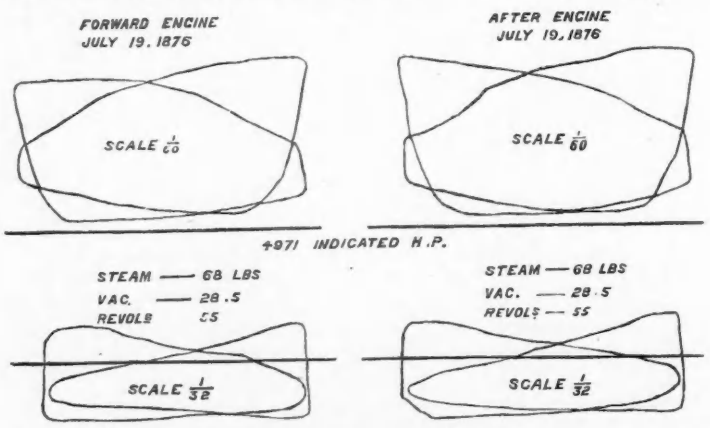


Fig. 37—DIAGRAMS FROM THE BRITANNIC'S ENGINES

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The next important advance was the construction of the Britannic and Germanic in 1874-5. These vessels were engined by Messrs. Maudslay and Field. We illustrate the engines of the Britannic in Figs. 32 and 36. They had two high-pressure cylinders 48in. in diameter, and two

low 83in. in diameter, with a stroke of 5ft., giving capacities of 1 to 3. The crank shafts were 18¾in. diameter at the bearings, with crank pins 20in. diameter by

From England.

Date.	Winds.	Courses	Dist's.	Latitude.	Longitude.	Weather.
1876.						
Sept. 21	Left Liverpool		1.5 p.m.			
,, 22	Arrived Queenstown		7 52 a.m.			
	Left Queenstown		5.10 p.m.	Roche's		Point abeam
		S.W.		North.	West.	
,, 23	S.S.W.	Various	270	51·22	15·12	Fresh breeze
,, 24	Westerly..	88	361	51·12	24·46	Fresh breeze
,, 25	W.	80	342	50·14	33·36	Strong breeze
,, 26	N.	71	371	48·15	42·30	Mod. breeze
,, 27	Variable..	69	390	45·53	51·21	Variable
,, 28	Variable..	67	391	43·21	59·43	Variable
,, 29	W.	71	371	41·21	67·34	Strong breeze
,, 30	To S. Hook	...	292	...	Arrived 6.24 a.m.	
		Total	2788	knots		

Mean time, 7 days 17 hours 36 minutes.

From America.

Date.	Winds.	Courses	Dist's.	Latitude.	Longitude.	Weather.
1876.						
Oct. 7	Left Company's Wharf			7.43 a.m.		
	Discharged pilot			10. 10 a.m.	Proceeded full speed	
				North.	West.	
,, 8	N.W. ...	N. 88 E.	392	40·40	65·26	Fresh breeze
,, 9	Westerly..	84	345	41·20	57·26	Moderate
,, 10	Westerly..	76	370	42·52	49·28	Moderate
,, 11	Westerly..	64	352	45·24	42·08	Moderate
,, 12	S.W. ...	66	365	47·54	34·00	Strong breeze
,, 13	N.W. ...	69·2	366	50·01	25·20	Strong breeze
,, 14	W.N.W. ..	79	375	51·14	15·41	Strong breeze
,, 15	To Roche's Point		290	Arrived 7 a.m.		
				Roche's Point	out 8 3 a.m.	
,, 15	In Channel ..		...	Arrived Bar Lightship 10 15		
				Rock Light 11. 2 p.m.		[p.m.
		Total	2875	knots		

Mean time, 7 days 16 hours 28 minutes.

21¼in. long; crank webs 14¾in. wide and 21¼in. deep; length of throw, 2ft. 6in. The tunnel shafting was 18in. diameter, and the propeller shaft 19in. diameter. The connecting-rods were 10ft. between centres, 11¼in. diameter at the bottom end, tapering to 9⅜in. at the top end.

drag links, as shown in Fig. 34, and worked into an oil cylinder, fitted opposite the steam cylinder, to steady the motion of the gear, and to avoid any shock in the event of the pressure in the steam cylinder acting too rapidly. The safety valves were loaded to 75 lb. Steam was supplied by eight oval boilers, double-ended, with thirty-two furnaces, 6ft. 6in. long by 3ft. 3in diameter. The boilers contained 2432 tubes, with a total heating surface of 19,500 square feet. These boilers were remarkable by in a way marking the transition from the old "box" low-pressure boiler to the modern cylindrical boiler. Fig. 33 gives sections of the boilers, which were made up of two semicircles united by flat sides, stayed as shown. A

Herewith is an abstract of the log of this vessel's last round voyage—see table. On the outward trip, the Britannic delivered her mails - 253 bags—at the Post-office at 10.45 a.m., on Saturday, the 30th September, being the morning of the eighth day after leaving port. On the homeward trip, her mail was in the hands of merchants in London and the Provinces by the first delivery on Monday morning, the 16th October.

This log is very interesting. It must be remembered that in 1876 the Britannic was the fastest ocean steamer afloat. Under the command of Captain Thompson, who took care that the best was got out of her, she four times in succession steamed across the Atlantic in less than

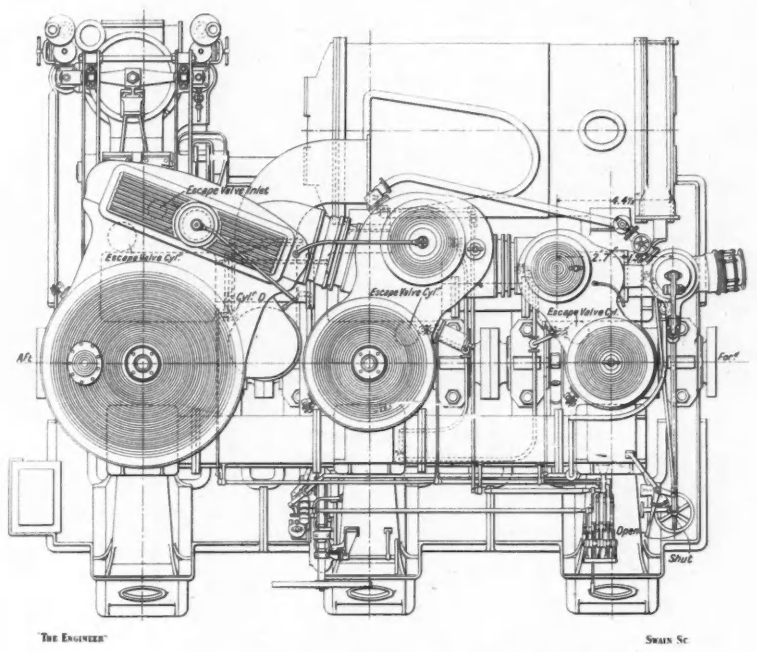


Fig. 38—PLAN OF CRETIC'S ENGINES

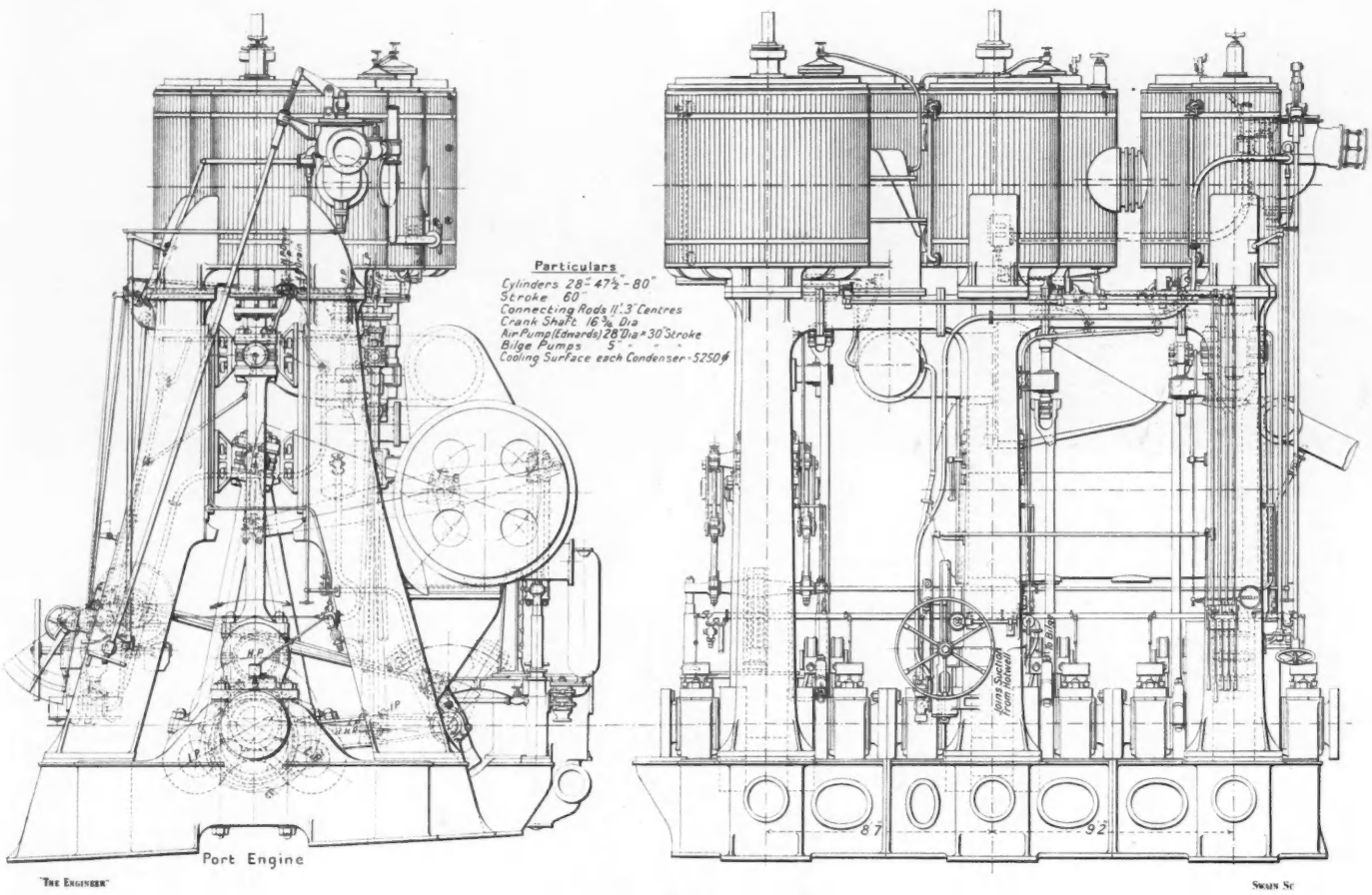


Fig. 39—ENGINES OF THE CRETIC

The crosshead brasses were 9½in. diameter by 10in. long, bolts 4½in. diameter. Crank pin brasses 20in. diameter by 21¼in. long, with bolts 6in. diameter. The main bearing bolts were 5⅞in. diameter. The slide valves were actuated by double bar link motions with sector bars 2½in. wide by 7½in. deep, and 2ft. 8in. between excentric rod pins. The excentric rods were 4½in. diameter at the top end, fitted with brasses 4½in. diameter by 3½in. long. Reversing was effected by direct action from a steam cylinder, and also by hand gear. The piston-rod of the reversing cylinder was connected by a crosshead to the cylindrical steam chest lay in the upper part of the uptake, and acted as a superheater. So far as we are aware, this type of boiler was first proposed by a Mr. Macfarlane about the year 1854. It appears to have given perfect satisfaction in the Britannic. We give here - Fig. 37—four diagrams reduced to half size, which show a very good valve setting indeed. The arrangement of the surface condenser was peculiar, lying as it did athwartships. There were six excentrics, the high-pressure slides carrying cut-off valves on their backs, worked by the extra excentrics.

eight days. The figures are as follows :—

Voyage outwards, 1876.	d.	h.	m.
10th June	7	16	36
11th July	7	19	57
12th August	7	20	46
13th September ...	7	17	37
Average ...	7	18	44

Voyage homewards, 1876.	d.	h.	m.
10th June	7	19	48
11th July	7	22	31
12th September ...	7	22	55
13th October... ...	7	16	23
Average ...	7	20	25

On the four outward trips the Britannic ran a distance of 11,216 knots, being an average of 2804 per trip, which

gives a speed of a little over 15 knots, or an average of 360 per day. Homewards she steamed 11,549 knots, or 2887 per trip, or 15.32 per hour, or 367.68 per diem. There was nothing on the ocean at that time to equal this performance.

The Britannic, as noted on an earlier page, was fitted with a raising and lowering propeller, Fig. 35, the stern

Fig. 40 BOILERS OF OCEANIC

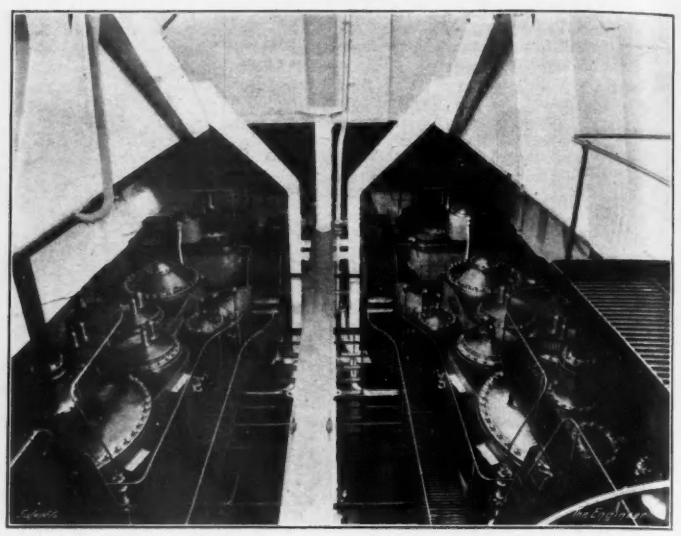


Fig. 41—ENGINE-ROOM OF OCEANIC

being altered so as to give a hollow recess in the hull in which the after length of the shaft could move vertically, being coupled by a universal joint to the tunnel shafting. The stuffing-box worked in a radial gland arranged to accommodate the angle of the propeller shaft when lifted. The idea of the inventor was to enable the propeller to be lowered when the ship was in

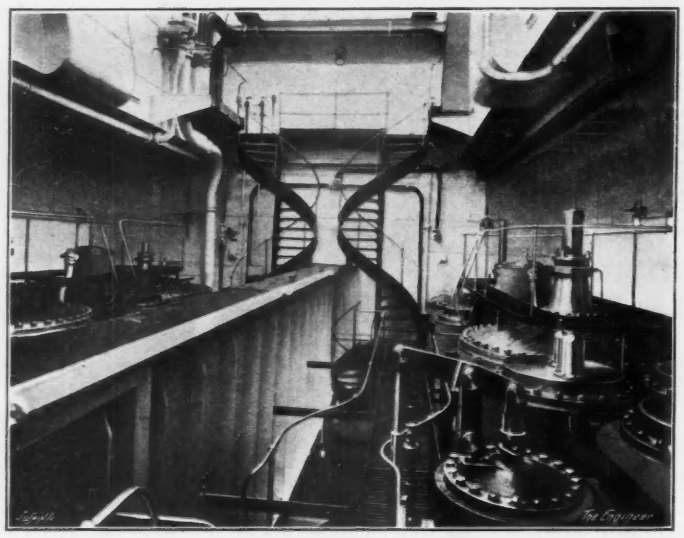


Fig. 42—ENGINE-ROOM OF OCEANIC

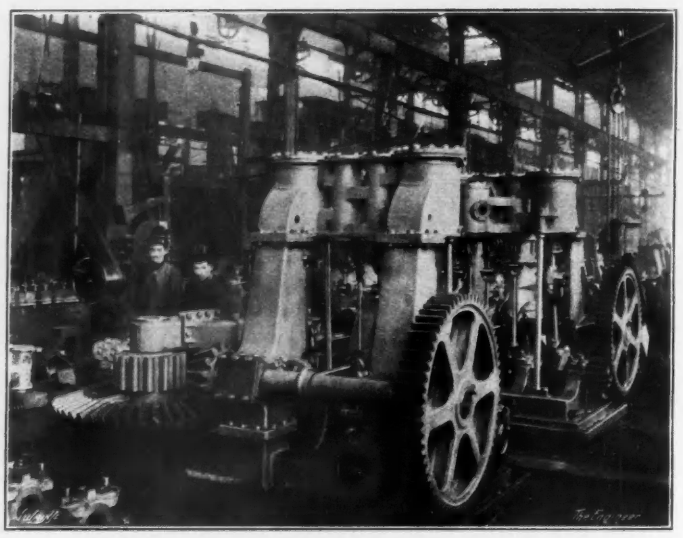


Fig. 43—STEERING ENGINES OF OCEANIC

deep water till the shaft almost touched the keel, so obtaining more solid water and rendering the screw less liable to race when pitching in a heavy sea. The engines were placed in the ship so as to rake aft in order to bring the whole of the shafting into alignment when the propeller was revolving in its lowered position. The radial gland and stuffing-box were sources of considerable anxiety during the trial runs in Belfast Lough. The flange securing it to the water-tight bulkhead developed a crack, and it was a matter of conjecture how far this crack would extend, and the hand stationed to watch it had visions of a race with the water up the long tunnel to the engine-room. The entrance to the tunnel from the engine-room was fitted with a D-shaped door, hinged at the sill so that it should be lifted up and automatically closed by the rush of water, in the event of the tunnel being flooded. The other means of escape was a vertical ladder in a tube rising to the upper deck. The lifting propeller and shaft were eventually taken out, and the shafting fitted in the usual manner. The Camel, a transport owned by Messrs. Harland and Wolff, was fitted with a similar arrangement of lifting propeller some time before it was tried on the Britannic.

Here something may be said concerning the price that must be paid for speed. According to Sir W. White the Germanic and Britannic each cost about £200,000 and averaged 15 knots. In 1889 an average speed of 20 knots was associated with a cost of £350,000 to £400,000. Five years later the corresponding figures were 22 knots and about £500,000 to £550,000. In 1899 the second White Star Oceanic cost £700,000. Particulars of the cost of later ships are not available, but the "Mercantile Cruisers Committee" of 1902, after careful inquiry, stated that the cost for 23 knots would be £575,000, for 24 knots £850,000, and for 25 knots £1,000,000. It is possible that these estimates are below the actual costs of the Deutschland and the Kaiser Wilhelm II.; probably these ships with 23 knots to 23½ knots speed would involve an expenditure of about £700,000 and £800,000 respectively. While the advance from 15 knots to 20 knots was made for an increase of, say, 80 per cent. in cost, that from 20 knots to 23½ knots has involved an increase of 100 per cent. to 130 per cent. And the rate of increase must continue to grow as the speeds rise. In steam navigation *c'est le dernier pas qui coûte*. No wonder that the Mercantile Cruisers Committee with these results before them concluded that commercial companies would require annual subsidies "towards making good the loss which would be sustained in peace time by running such

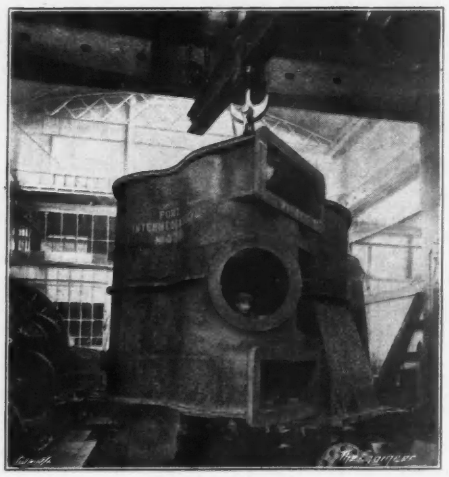


Fig. 44—CYLINDER OF OLYMPIC

vessels." They suggested annual subsidies ranging from 2.6 per cent. on first cost of 20-knot vessels to 15 per cent. for 25-knot vessels. For 23-knot vessels the subsidy proposed was 8.6 per cent. The subsidy for 20-knot vessels agreed with that provided for in the Admiralty scheme already in force; but no higher payment than £10,000 per annum was contemplated in that scheme, and vessels of 22 knots speed received that sum, whereas the Committee recommended £40,000.

Into the question of subsidies, however, it is not our purpose to go. All the facts confirm the accuracy of Dr. Lardner's much abused statement that Atlantic steam navigation could not be made to pay without subsidies for the conveyance of the mails. The conditions have altered, but the general fact remains as it was. It must not be forgotten, however, that the augmentation in first cost is due very largely to the expenditure on fittings, which are infinitely more luxurious in a big ship than they ever were in a small one.

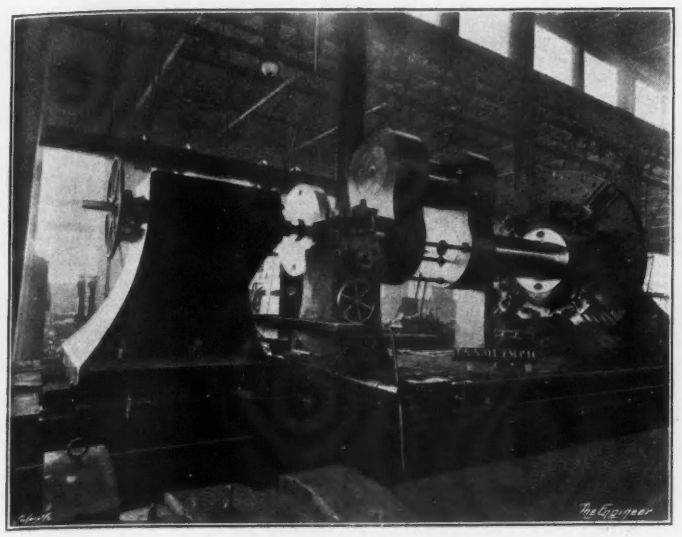
With the Germanic and Britannic, the White Star Company remained content until 1881, when the Arabic and Coptic were built for the trans-Pacific trade. In 1883 came the Ionic and Doric for the New Zealand trade, and in 1885 the Gaelic and Belgic replaced two older ships of the same name. There was nothing about the machinery of these ships which calls for special mention. Three years later came the Cuffic and the Runic. Then came a new departure; twin screws were adopted for the first time by the company.

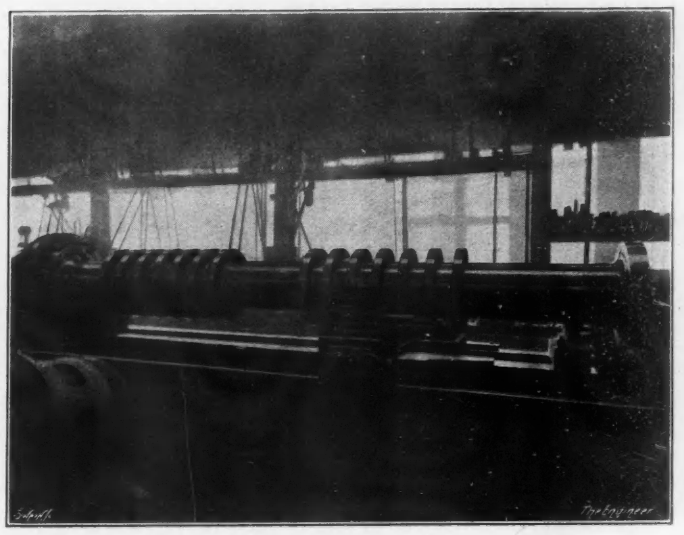
The twin screw is so freely used now that the difficulties met with in getting it adopted can scarcely be realised. The idea was very old; twin screws had been proposed and patented from a very early period. But the distance between a patent specification and a model and a sea-going steamer is very great. In the year 1860 there was an enterprising and able firm of engineers, Messrs. Dudgeon, carrying on business on the Thames. Among other work, they undertook the engines for certain steamers known as tea clippers; they were really blockade-runners. The late Capt. Symonds, R.N., was a warm advocate of twin screws, and it is to him and Messrs. Dudgeon in the main that the world is indebted for the twin screw. We quote here from a paper read before the Institution of Naval Architects. "Since March, 1862, we have completed twenty twin-screw steamers of varying tonnage up to 1500, and 300 nominal horse-power.* First we built eight vessels of 425 tons

* Probably 1000 indicated horse-power in the ordinary way, but some of the blockade-runners had forced draught, with closed ash-pits and fans.

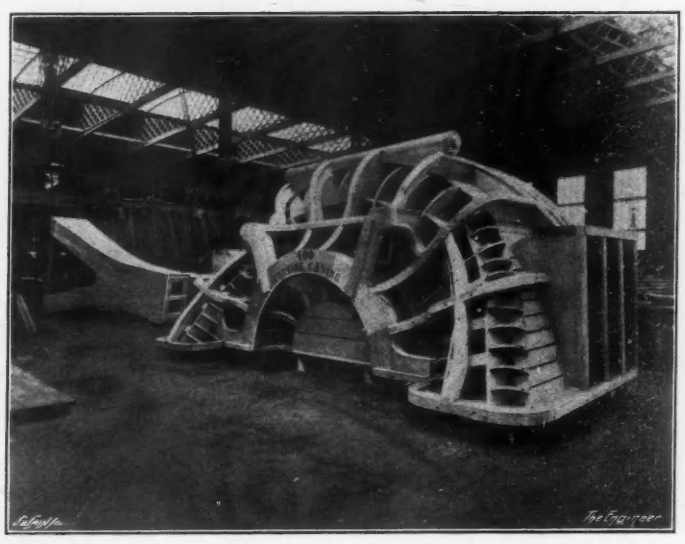
and 120 horse-power, all designed for blockade running. They have all been very successful in that hazardous trade, some running as many as a dozen times, the average number of runs being five. At their trial trips they gave the following results:—With an indicated horse-power = 600, attained with four cylinders 26in. diameter by 24in. stroke, steam 23.5 lb., vacuum 26in., revolutions 115, the vessels went 14 knots. The immersed midship section was 150 square feet, and the displacement 400 tons; the consumption 15 cwt. per hour." A larger blockade-runner was the Edith, 531 tons and 200 nominal horse-power. On her trial trip she made 13.4 knots, with 894 indicated horse-power. There were two pairs of cylinders, 34in. diameter by 26½in. stroke; revolutions, 108. Immersed midship section, 180 square feet, displacement 510 tons, consumption 24 cwt. per hour. One of the best, if not *the* best, steamer built by Messrs. Dudgeon, was the Mary Augusta, illustrations of whose engines will be found in THE ENGINEER for October 26th, 1866. These engines had four cylinders, 40in. diameter, 22½in. stroke. The boiler pressure was 32 lb., and with a vacuum of 25½in. and 118 revolutions, she indicated 1750 horse-power, and attained a trial trip speed of 16.2 knots. The displacement was 940 tons, and the consumption of coal 2.3 lb. per indicated horse-power per hour. This was a very fine performance for that period. All Dudgeon engines were horizontal, the object being to keep the machinery as far as possible below the water line, and so safe from Federal guns.

Curiously enough, little or nothing was done with twin screws for several years after peace was declared. The Admiralty, in this period, ordered two twin-screw armoured gunboats, and one small light draught ironclad, the Penelope. A few foreign warships were also fitted with twin screws at this time. Nearly all ocean steamers and warships, however, had single screws, and so long as sail power was regarded as of great value, twin screws were not favoured generally; partly because they greatly interfered with efficiency under sail, and partly on account of dependence on sail in case of a breakdown of the machinery. In 1866 the ill-fated Captain was laid down with twin screws, and followed soon after by four vessels of the "Invincible" class; some coast defence vessels which had no sail power were also fitted with duplicate propellers. When the so-called "mastless" type of seagoing ironclads was introduced in 1869, with no sail power, recourse was necessarily had to twin screws as a security against total breakdown; the fact being fully recognised, which has in recent years been repeatedly demonstrated, that a twin-screw ship could make fair speed and be perfectly under control with only one engine and screw at work.





Figs. 45 and 46—CRANK SHAFT AND THRUST SHAFT OF OLYMPIC



Figs. 47 and 48—TURBINE CASING PATTERNS FOR THE OLYMPIC

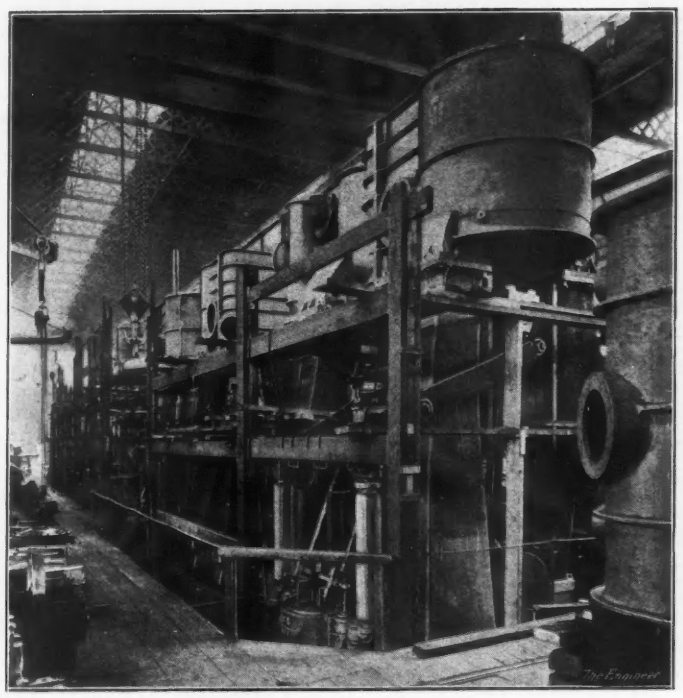


Fig. 49—ENGINES OF THE OCEANIC, 1899

Coming now to the later boats of the White Star Company, Sir W. White, in the presidential address before referred to, said:—"Little was done towards adopting twin screws in mail steamers for eight or nine years. Then came the question of realising 20 knots on the Atlantic service; and my friend, the late Mr. Thomas Imray, who had carefully studied my statements of 1878, consulted me when the design of the Teutonic and Majestic was being prepared by Messrs. Harland and Wolff. Enlarged experience had only confirmed my conviction and emphasised my recommendation of twin screws. They were adopted in the ships named, and in the two 20-knot ships built for the Inman line about the same time, the City of Paris and City of New York." The Teutonic was begun in March, 1887, and started on her first voyage to New York on the 7th of August, 1889. Her sister, the Majestic, started on her first voyage the 2nd of April, 1890.

		Passage.	Distance Knots.	Speed.
	1891.	d. h. m.		
Majestic ...	July	5 18 8	2777	20·11*
Teutonic ...	Aug	5 16 31	2778	20·35*
	1892			
Majestic ...	Feb.	5 20 22	2865	20·41*
Teutonic ...	Aug.	5 18 46	2775	20·00
Majestic ...	Sept.	5 18 47	2782	20·05
	1896.			
Majestic ...	Aug.	5 17 56	2780	20·15

* Fastest then on record

A very complete set of illustrations of the Teutonic and her machinery will be found in THE ENGINEER for December 19th, 1890. These were, no doubt, the two finest mail steamers afloat at the time. The above list of passages may be compared with that setting out the performance of the Britannic given on

page xiii. Introduced first in order to obtain plenty of screw surface in shallow water, and facility of manœuvring, perpetuated because twin screws represented two strings to the bow, they have ultimately come to be used of necessity, because powers have become too great to be exerted through a single shaft on a single propeller. The single screw Cunard ship Etruria, at one time the finest vessel in the Atlantic service, worked up to 14,000 horse-power, and this was held to be attempting too much. Nevertheless, she ran with great success for many years, engines, balanced on the Yarrow, Schlick, and Tweedy plan, the low-pressure cylinders being on the end cranks. The cylinders are 47½in., 79in., 93in., and 93in., and the stroke is 72in. The propellers, which are of manganese bronze, are 22ft. 3in. diameter by 32ft. pitch, and the plating of the shaft is carried right to the aft brackets, so that no part of the shaft is exposed to the sea. Several views of her machinery will be found on page xiv. She has fifteen cylindrical boilers with 96 furnaces, a grate area of 1962ft., and a heating surface of nearly 75,000 square feet. She is an exceptionally well appointed vessel, and for this reason and on account of her high speed, is one of the most popular in the White Star Atlantic service. Her owners intended that she should be a perfectly reliable "week" boat, and she has easily maintained her reputation. Her first voyage was made in 6 days 2 h. 27 min. She could circle the world in 81 days without re-coaling. She marks so far as this line is concerned the high-water mark of reciprocating engines. The next stage in the history of marine engineering is the introduction of the turbine. Unlike the Cunard Company, Ismay, Imrie and Co. decided not at once to give up the reciprocating engine, but adopted the more conservative course of combining the two systems. Hence, the Laurentic was built in 1908 and fitted with two reciprocating engines and one turbine. A full description of her will be found on page iii. She has run now for some time on the Canadian service with such success that the same system of propelling machinery has been adopted for the Olympic and Titanic.

In concluding this very brief sketch of the vessels of the White Star Line, it is only fitting to recall the part they play in the protection of their country. It is owing mainly to Mr. Ismay that the British Navy is able, in case of war, to call upon the services of the fastest vessels in the mercantile marine. It was at the time of the Russo-Turkish war, when there seemed some danger of this country being involved, that he offered to put several liners at the disposal of the Government. The idea was considered so excellent that in later ships special arrangements have been made, so that they may, in case of need, be quickly converted into high-speed cruisers.

Fig. 50—AFTER SHAFT BRACKETS OF THE TITANIC

the only bad accident she had being the breakage of her screw shaft once rather far down in the tunnel.

The last high-speed vessel to be built for the White Star Line is the Oceanic, still one of the favourites of the Atlantic service. She was built in 1899, is 685ft. 6in. long, and has an average speed of 21 knots. Her horse-power is no less than 28,000—far greater than that of any vessel already in the White Star service, but very much less than that projected for the Olympic and Titanic, which are also expected to make 21 knots. The Oceanic is propelled by two sets of four-cylinder triple-expansion